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A CRITICISM OF THE PROPOSED STANDARDS FOR 16-MM. SOUND-FILM*

J. A. MAURER AND W. H. OFFENHAUSER**

Summary.—*It has been proposed that the standard dimensions of 16-mm. sound-prints be changed, principally by widening the sound record and scanned areas. The question is reviewed from the standpoint of the cumulative effects of film shrinkages and mechanical inaccuracies in the steps leading to the final sound-print and in the projection of that print, following the method described by R. P. May in the April, 1932, Journal.*

A film having sound records of various widths supports the contention that increased width of sound-track is not needed, and that if any change from the present standard is to be made, it should be in the direction of a narrower track to provide a wider margin outside the sound-track and a wider safety area between the sound-track and the picture.

The present dimensional standards of sound-film, both 35-mm. and 16-mm., reflect the fact that sound was added to the motion picture long after these two film sizes had been standardized for silent pictures. The silent film standards necessarily limited the amount of space on the film that could be made available for the sound. How much more space the sound engineers would have liked to have can be seen by comparing our present standards with the wide films of 1929 and 1930, in which the sound-track was approximately three times as wide as the ones we use today.

Because the space that could be taken for the sound record was thus limited, a second conflict of interests necessarily arose between two classes of sound engineers. What might be called the optico-photographic group naturally wished to use as much of the available space as possible for the sound-track. At the same time the mechanical engineer designing the sound equipment logically demanded a certain amount of space for mechanical handling of the film and for providing tolerances against inaccuracies in guiding.

The compromise between the two requirements was bound to prove

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received May 4, 1938.

** The Berndt-Maurer Corp., New York, N. Y.

unstable in a rapidly advancing art. Every improvement in mechanical accuracy naturally encouraged those who wished to enlarge the sound-track at the expense of the safety areas. Conversely, every improvement in film stock or in recording or processing technic that increases the volume range attainable from the track might serve as an excuse for the mechanical designer to call for a relaxation of the narrow dimensional limits that hold him, as it were, in a strait-jacket. If he does not protest, it is because the mechanical engineer rarely lays claim to any very complete knowledge of photographic and optical requirements in recording and reproduction. Not feeling sure of his ground, it is only when he is pushed too far that he rebels against the tendency to increase the width of the track at the expense of the safety areas.

In the JOURNAL of the Society for March, 1938, there appeared a report of the Standards Committee[1] in which a considerable number of revisions in the standards are proposed for adoption by the Society. So far as these revisions relate to sound, they consist mostly of increases in the width of the sound-track areas, with corresponding reductions in the width of what we have been calling the safety areas.

The authors have studied with particular care the proposals relating to 16-mm. sound-films. Briefly, they feel that these new proposals seriously unbalance a situation that was already unfavorable for the mechanical designer, and that they do so without gaining any perceptible advantage in the way of better sound reproduction. Therefore, in response to the published invitation[2] to discuss the proposed revision of the standards, this analysis of the problem is presented by the authors as they see it.

A brief historical review may serve to illuminate several of the points at issue. The present system of 16-mm. sound-film standards originated in the proposal made by R. P. May[3] at the Swampscott meeting of the Society in the Fall of 1931. The standard that Mr. May proposed was based upon a careful study of the various errors in track location that were likely to occur in going from a 35-mm. original sound-track through the steps of re-recording on 16-mm. film and contact-printing the resulting sound negative, followed by running the print on a projector. A study was made also of the case in which the sound-track was directly re-recorded to the print. Adding up the possible errors, Mr. May arrived at the interesting conclusion that a film 0.660 inch wide (instead of the standard 0.630 inch) would be required to accommodate what he believed to be a sufficiently

wide track, plus full provision for overlap of the scanning beam, and safety areas wide enough to provide for proper mechanical support. But, on the assumption that all the possible errors would hardly ever accumulate in one direction, it was believed possible to arrive at a workable standard within the limits of the 0.630-inch film. The standard that was proposed had substantially the same track width as the one that was adopted in 1934, but placed the track center-line 0.045 inch from the edge of the film instead of at the present standard distance of 0.058 inch. A safety area 0.0284 inch wide was provided between the printed area of the sound and the printed area of the picture.

The standard that was set up in November, 1934,[4] is shown drawn accurately to scale in the top half of Fig. 1. It will be noticed that the safety area between the picture frame and the space allotted to variable-density sound-track was reduced to 0.012 inch. On the other side of the track was provided a fairly comfortable space of 0.018 inch between the variable-density track and the edge of the film. But the principal objection to this standard was the small allowance for sound-track weave. The variable-width track was set at 0.060 inch; the scanned area was only 0.065 inch wide; therefore, the allowance for weave was only 0.0025 inch in each direction, which is insufficient. So far as the authors are aware, no manufacturer of projection equipment followed the standard in this respect. Scanning-beam lengths used in practice varied from 0.070 inch to 0.080 inch with different manufacturers.

After 1934, the process of optically reducing the sound-track from 35-mm. negative to 16-mm. print became the most widely used method of producing 16-mm. sound-films. Certainly the excellence of the results that were attained justified the widespread adoption of the method. But this brought with it a complication of the standards problem. Optical printers were designed to reduce the 0.071-inch variable-width track on the 35-mm. film to a width of 0.060 inch on 16-mm. film. This ratio of 60 to 71 gave a reduced variable-density track having a width of 0.0845 inch instead of the 0.080-inch width called for by the 1934 standard.

Eventually the 35-mm. standard was changed to specify a track space 0.076 inch wide in variable-width recording. This track, on the optical reduction printer, gave a 16-mm. print having a track width of 0.0642 inch.

These two dimensions—0.0845 inch for the variable-density track,

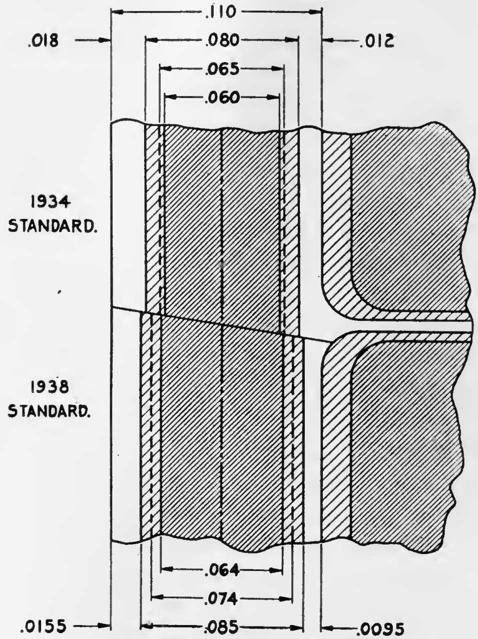

FIG. 1. SMPE standard.

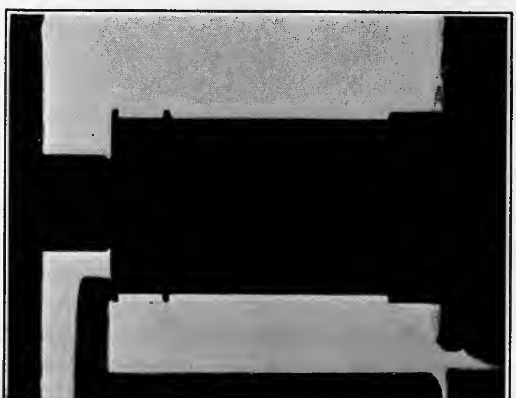

FIG. 2. One form of idler construction.

and 0.0642 inch for the variable-width track—are substantially those called for by the 1938 specification. As was logical, the width of the scanned area has been set at 0.074 inch, a value providing equal tolerances for weave on the two types of track.

Thus, while the 1938 proposed standard follows present commercial practice, it seems to have been arrived at by a process of commercial evolution rather than by any process of careful analysis. Standards arrived at in this way are likely to contain defects that will sooner or later lead to a desire for modification.

Before drawing definite conclusions, however, let us analyze the new standard step by step. In the first place, does it provide suitable allowance for side motion of the film and for accumulated inaccuracies in the location of the sound-track? The method of study described by Mr. May should give the answer.

The two processes in use today—optical reduction and direct recording—give about equal opportunities for mislocating the track. Let us study the optical reduction method.

We have 35-mm. film carrying a sound-track that is officially permitted[5] to be 0.003 inch out of position, in the direction toward the picture. This film must be guided through one side of the optical printer. If the guiding is done by the best available means, it can be made accurate to about 0.001 inch, but hardly better than that. Thus, up to the point where the printing light-beam passes through the negative film, there is a possible error of 0.004 inch in the location of the 35-mm. track. Reduced through the optical system, this becomes 0.0034 inch.

The 16-mm. film must be guided also on the optical printer. Allowing again an error of 0.001 inch in guiding the film, the total possible error in track location on the 16-mm. film becomes 0.0044 inch.

This film must be run on the 16-mm. projector. At the sound translation point it must again be guided. But at the sound translation point the film needs to be left as free as possible to move with uniform speed, and this condition is not compatible with extreme accuracy of guiding. The method that most projector manufacturers have adopted is to pass the film between guide rollers or flanges placed a fixed distance apart. If the film is fresh, this method will guide it within 0.002 inch, but when shrinkage has reached a value of around one-half of one per cent,* the film is 0.003 inch narrower, and the

* As set forth in a corollary paper "The Shrinkage of Acetate-Base Motion Picture Films," by J. A. Maurer and W. Bach (see page 15 of this issue),

error in guiding is more likely to be 0.005 inch. Adding this to the error of location that may occur in printing, we find that the sound-track may in some cases be as much as 0.009 inch out of central location with respect to the scanning beam.

The 1938 standard allows a tolerance of 0.005 inch before any part of the track misses the scanning beam. This is defensible on the basis that most of the time the errors enumerated above will partly cancel each other instead of adding, and therefore in most cases the total error will be less than 0.005 inch.

Referring now to the picture standards, we find that the standard camera aperture is 0.030 inch wider than the standard projector aperture. This permits a weave of 0.015 inch toward either side of the picture gate, which is three times as much as is allowed for the sound-track.

This difference becomes significant when we turn our attention to the matter of the safety areas. As shown in the lower half of Fig. 1, the safety area between the picture and the variable-density sound-track (or printed area) has now been reduced to 0.0095 inch. The safety area at the edge of the film has a width of 0.0155 inch. *In these two narrow spaces* the projector manufacturer must locate his supporting strips for handling the sound-track edge of the film where it passes around sprockets and rollers and where it is fed through the picture gate.

Fig. 2 shows the type of idler construction that one prominent projector manufacturer has been forced to adopt in the attempt to cope with this situation. If the observer remembers that the idler roller in this illustration is only $^1/_4$ inch in diameter, he will realize how very tiny these two rounded ridges are. Yet they, and others like them on the sprocket drums and in the picture gate, are all the support it is possible to give to the sound-track edge of the film in its passage through the projector.

It is the writers' opinion, based to a considerable extent upon observation of what has happened to sound-prints in the field, that no

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the shrinkages to be found in current films in use measurably exceed the 0.5 per cent assumed in this discussion. For example, it has been not unusual to find in film libraries film that has shrunk considerably more than 1 per cent. Recently it has been observed that there seems to have been a change in the base of this particular stock, which change indicates that 0.5 per cent will be a reasonable figure for the future. The stocks of other manufacturers point to the same possibility. The film manufacturers are to be commended for their progress in thus contributing to the solution of our knotty standards problem.

type of metal, no method of plating, and no technic of polishing, can prevent the scratching of the film by a supporting strip as narrow as is required by this 1938 standard proposal. The pressure per unit area on the film is too great. Clean new films will go through a clean projector without perceptible scratching, but as soon as the film accumulates a little dust and grit, the scratches appear. And, more often than not, they find their way into the scanned area, because weave in the picture gate and at the sprockets and idlers can not be reduced to zero.

These remarks are not intended in any way as a criticism of the projector manufacturers or their products. The authors feel that the manufacturers have accomplished all that is mechanically possible within the limits imposed by the standard. But it is also felt that much better mechanical design would be possible if larger safety areas could be provided on the film.

In order to provide larger safety areas we must either (*a*) reduce the width of the sound-track and scanned area or (*b*) reduce the allowance for picture weave. We suggest doing both, in moderation.

The objection will immediately be raised that any reduction of the width of the sound-track means a reduction of the available volume range. We propose to demonstrate that this loss is much less serious than it is commonly believed to be.

Suppose that the modulated track-width of a record is reduced from 0.064 to 0.060 inch. The difference in reproduction level is 0.54 decibel. A change of this magnitude is inaudible. If the track-width is reduced from 0.064 inch to 0.057 inch, the difference in reproduction level is one decibel. This is about the smallest difference in level that can be detected. Volume controls on monitoring loud speakers and the like are commonly made with steps of two decibels.

When the width of a sound-track is reduced, the background noise level diminishes almost, though not quite, as fast as the overall level, and the result is that the volume *range* is reduced much less than the volume *level*. Therefore, alterations in track-width that produce inaudible or barely audible changes in volume *level*, produce wholly negligible changes in volume *range*.

(In order to permit the Society to judge these effects, the authors had prepared a number of recordings of a given musical selection, using different maximum track-widths. This film was played at the close of this presentation, to support the contention that no harm is done by moderately reducing the track-width.)

To accomplish this reduction requires, of course, a modification of

existing optical reduction printers. Such modification is not difficult. In many of the machines in use at the present time, a pair of cylindrical lenses is used to obtain unequal magnification in forming the image longitudinally and laterally with respect to the sound-track. In most cases a slight change of the positions of these cylindrical lenses in the system is all that is required to give the necessary slight change in the lateral reduction ratio.

Any change of standards must be made with caution in order to avoid impairing the performance of the large number of 16-mm. sound projectors now in use. In view of this consideration, we suggest that it is proper to retain the track-widths of the 1934 standard, which we know reproduce satisfactorily on existing projectors.

These track-widths were 0.080 inch for the variable-density record, and 0.060 inch for the variable-width record. The present standards for 35-mm. film are 0.100 inch and 0.076 inch. If we adopt an optical reduction ratio of 0.8 instead of the present ratio of 0.85, we shall obtain track-widths of 0.080 and 0.0608 inch, respectively, for the variable-density and variable-width records. This is close enough to the 1934 standards. The width of the scanned area can logically be made 0.070 inch, which will give substantially the same tolerance for weave as the 1938 standard proposal.

In case 35-mm. negatives having the old track-width of 0.071 inch are reduced on optical printers having an 0.8 ratio, a 16-mm. track-width of 0.0568 inch will be obtained. As has been pointed out, a track of this width is only one decibel lower in level of reproduction than the 0.064-inch track called for by the 1938 standard. Therefore, no perceptible sacrifice of performance is involved.

The change of track-widths just discussed would gain 0.0025 inch for each of the two safety areas on the film. In order to gain additional space for the safety area between the sound-track and the picture, we suggest a slight change in the width of the standard camera aperture.

This is by no means as revolutionary a suggestion as it may at first appear. A situation has existed ever since the introduction of optical reduction printing that has made it impracticable to conform exactly to the official standard. This situation came about because the ratio of height to width of the 35-mm. projector aperture as standardized after the introduction of sound is not quite the same as the ratio of height to width of the standard 16-mm. projector aperture. It is not easy to decide whether to reduce the picture in the ratio of the

heights or in the ratio of the widths. It has been suggested by the Standards Committee that the Society ought to establish a standard reduction ratio for printing picture on 16-mm. film from 35-mm. negatives, but no final decision has been taken.

This ratio problem has been subjected to thorough analysis by G. Friedl, Jr.,[6] with whose conclusions we are in general agreement. Mr. Friedl recommends that the ratio of reduction be established as the ratio of the *widths* of the 35-mm. and 16-mm. *projector* apertures, that is to say, the ratio 0.825 to 0.380. If this is done the reduced image of the 35-mm. *camera* aperture is 0.400 inch wide. We suggest that this be made the standard width of the 16-mm. camera aperture, the projector aperture standard remaining unchanged. This will give a standard to which 16-mm. optical reduction prints can conform.

In one particular we wish to suggest a deviation from the recommendations of Mr. Friedl. In the 35-mm. standards there is a displacement of 0.006 inch between the center-line of the camera aperture and the center-line of the projector aperture. This is provided as an allowance for shrinkage. Mr. Friedl has recommended that the optical reduction printer be adjusted so as to place the center-line of the image of the area covered by the 35-mm. *projector* aperture on the common center-line of the 16-mm. camera and projector apertures. This gives an image of the 35-mm. *camera* aperture that is off center a trifle less than 0.003 inch, in the direction of the sound-track edge of the film. As Mr. Friedl has mentioned in his paper, this displacement is in the wrong direction to serve as a shrinkage allowance, since the 16-mm. standard assumes that the film is to be guided by the sound-track edge.

The authors suggest that the center-line of the image of the 35-mm. camera aperture, not the projector aperture, be made to coincide with the center-line of the 16-mm. film, which is the same as the center-line of the 16-mm. camera and projector apertures. This will give a margin of 0.010 inch of picture on each side of the 16-mm. projector aperture. The shrinkage that occurs during the first few projections of the print will then move the center-line in the proper direction to make the 16-mm. projected area identical with that projected from the 35-mm. film.

No harm will be done by changing the 16-mm. camera aperture standard to a width of 0.400 inch, since an allowance of 0.010 inch for picture weave will remain. This is sufficient for the modern projector, as is proved by the successful projection of optical reduction

prints in the past. At the same time a space of 0.005 inch will have been added to the safety area between picture and sound.

A suggested set of specifications embodying these two changes is shown in an enlarged true-to-scale drawing in Fig. 3. It will be noted that the safety area between the picture and the sound-track is now 0.017 inch wide instead of 0.0095 inch; that the two safety areas are of nearly equal width, the one of the edge of the film being 0.018 inch

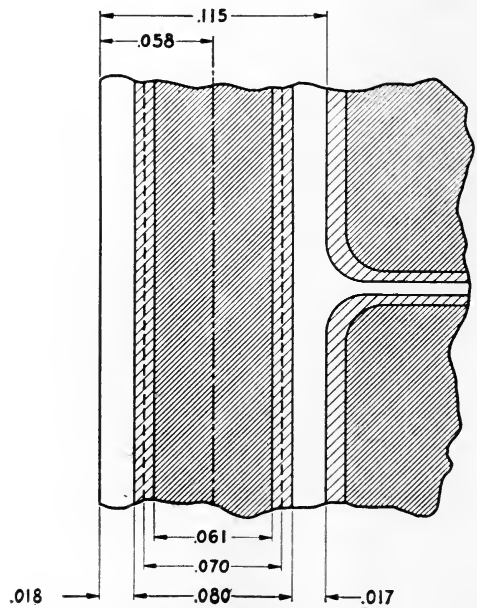

FIG. 3. Proposed specifications.

wide; and that the allowances for weave of picture and sound have been brought more nearly into agreement.

We believe that this set of specifications, if put into use, would cause substantially no difficulty during the period of transition, since films made in accordance with it would reproduce satisfactorily on existing projectors, while projectors built in accordance with this set of specifications would give satisfactory results with film made on existing optical reduction equipment. At the same time the changes are not trivial, since they result in nearly doubling the space available to the projector manufacturer for the placement of his film supports,

and thus make possible longer life and better performance on the part of both projector and film.

The philosophy that is the basis of this entire discussion can be stated very briefly. We believe that better and more uniform sound can be reproduced from an undamaged track of moderate width than from a wide track that has been mutilated by scratching. Further, we believe that improved overall performance can be achieved under a set of specifications that provides for the customary machine-shop tolerances in making the parts that touch or support the film in the projector.

We recognize that certain assumptions have been made throughout this discussion that may not be in agreement with the opinions of others. Further discussion seems desirable. We suggest, therefore, that action upon the proposed standards for 16-mm. sound-film be postponed until a more complete consensus can be obtained.

REFERENCES

[1] "Revision of SMPE Standards Proposed for Adoption by the Society," *J. Soc. Mot. Pict. Eng.*, **XXX** (Mar., 1938), No. 3, p. 249.

[2] *Ibid*, p. 249.

[3] MAY, R. P.: "Sixteen-Mm. Sound-Film Dimensions," *J. Soc. Mot. Pict. Eng.*, **XVIII** (Apr., 1932), No. 4, p. 488.

[4] "Standards Adopted by the Society of Motion Picture Engineers," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Nov., 1934), No. 5, p. 247.

[5] *Cf* ref. 1, p. 267.

[6] FRIEDL, G., JR.: "Data Regarding Dimensions of the Picture Image in 16-Mm. Reduction Printing," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (June, 1937), No. 6, p. 585.

DISCUSSION

MR. CARVER: I should like to compliment Mr. Maurer for what seems to me to be the best criticism of a standard that I have ever heard at one of these meetings. It is to get such opinions as this that we publish the drawings as proposals, before validation by the Board of Governors. During the Committee's discussions of the drawings the dimensions were changed several times, mainly to keep up with changes that the manufacturers were making during the time. None of them seemed very satisfactory and we felt that it would be best to publish the drawings for wider criticism. The two drawings *DS35-7-1* and *DS 16s-7-1*, showing the 35-mm. and 16-mm. sound-tracks, were not validated as SMPE standards at the Board meeting on April 24th, and as a consequence are up for further study and alteration, if advisable. We hope, with the aid of your analysis, to arrive at a satisfactory answer.

MR. OFFENHAUSER: Mr. Maurer and I were not associated with the Standards Committee, and became aware of the nature of the Committee's deliberations

only when we received our copies of the JOURNAL for March, of this year, in which the proposed standards were printed.

While we have been interested in standards for a number of years, it was only about six months ago, and for entirely different reasons, that we began making shrinkage and other measurements, the results of which are applicable to this problem. Our direct preparation for this paper began when the proposed standards were published, and only at that time did we begin to collect data related specifically to the problem. It takes time to collect data. I believe that this procedure has to be followed in practically every instance where comment is made from outside the Society's Committees, in order that those offering the comment may be sure of their ground. We felt that a communication at this time was proper, inasmuch as the Standards Committee published an invitation to discussion in connection with the new standards proposal.

MR. TOWNSLEY: I hope that the Standards Committee will give some thought to arranging the final dimensions so that the lateral reduction ratio for optical reduction printing will be the same for variable-density and variable-width track.

MR. KELLOGG: We want to make sure that any step we take will be toward higher standards of performance, even if it should make certain jobs a little more difficult today, provided we do not make them excessively expensive.

Sometimes changing a standard in one direction may be a very simple matter while changing it in the other direction may mean serious difficulty. Regardless of the dimensions of the sound-track as now proposed, I do not see why the length of the scanning-beam in a projector should not be about as long as one can make it without getting over into the edge that needs the support, and coming dangerously close to the picture frame line. If many projectors are built with shorter scanning-beams, it will be practically out of the question to adopt a wider track later.

THE SHRINKAGE OF ACETATE-BASE MOTION PICTURE FILMS*

J. A. MAURER AND W. BACH**

Summary.—*A simple direct-reading film-shrinkage gauge has been constructed with which shrinkage readings may be made in a few seconds. The accuracy of the instrument is such that the maximum variation in a series of readings made upon a particular film will not be more than 0.02 per cent of the predetermined length measured. Readings have been taken systematically with this instrument over a period of five months to determine the shrinkage behavior of acetate-base films under various conditions of storage and use.*

The results indicate that the safety-base film made by each of the three American manufacturers has a characteristic value of shrinkage that is ordinarily reached within a few days after processing. Subsequent shrinkage is slow but continuous over a long period of time. The ultimate shrinkage is of the order of 1.25 per cent except in the case of films that have been projected many times on projectors using high-wattage lamps. The bearing of this shrinkage information upon equipment design is discussed briefly.

Ever since motion picture films were first made, it has been recognized that they shrink as a result of exposure to the air and to the various chemical baths used in the film laboratory. It has also been recognized for a long time that the shrinkage of acetate-base, or safety, films is greater than that of nitrate-base films, and, in fact, this is one of the principal reasons for the continued use by the industry of inflammable films in preference to safety films. The literature of the art contains numerous references to the fact of shrinkage but very little quantitative information about it. This is unfortunate, inasmuch as it is hardly possible to arrive at a comprehensive design of any part of a motion picture machine having to do with the handling of film without at least making some assumptions as to the range of film dimensions within which the machine will be required to operate.

With regard to nitrate-base film it is possible to gain at least a fair idea of these limits by studying the published material on sprocket

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 15, 1938.

** Berndt-Maurer Corp., New York, N. Y.

design. With respect to acetate base, however, a careful search of the past publications of the Society has indicated that they contain no information of any appreciable value about the shrinkage of this basic raw material of the 16-mm. industry.

As a first step toward the accumulation of a body of facts as to the shrinkage of safety-base films, the authors constructed the shrinkage gauge shown in Fig. 1. This gauge operates upon the simple principle of magnifying by a lever the differences in length occurring over 39 sprocket-holes of the 16-mm. film. One sprocket-hole is placed over a fixed pin at the left side of the gauge. The 39th sprocket-hole to the

FIG. 1. The shrinkage gauge in use.

right of this is placed over a pin on the short end of the lever. Between these two points the film lies in a channel between two parallel plates of metal separated by twice the thickness of the film. The upper of these plates is a flap which is closed down after the film has been laid in place. This arrangement serves to assure that the film will lie straight without kinks between the two measuring points. A light coiled spring attached to the pointer applies enough tension to overcome any tendency of the fulcrum bearing to stick, and to take up any possible looseness in this bearing, but does not apply enough pressure to cause the pin on the end of the lever to distort the edge of the sprocket-hole at which the reading is being taken.

The distance corresponding to 39 sprocket-holes was chosen as the

length of film to be measured because this length leaves no uncertainty as to which sprocket-hole is the one to be placed over the pin on the end of the lever, and thus it is not necessary for the person using the gauge to count the number of sprocket-holes in the length he is measuring. Thirty-nine holes were chosen, instead of the round number of 40, because this permits calibrating the gauge by the aid of an ordinary 12-inch machinist's vernier caliper. The scale was calibrated so that each division corresponds to 0.1 per cent of the standard perforation length for 39 sprocket-holes, plus the height of one sprocket-hole, which must be added because the two pins on the gauge are in contact with opposite sides of the sprocket-holes in which they are placed. This is 11.750 inches. Without introducing doubt as to which sprocket-hole was the correct one on which to measure, it was found possible to make the scale read all lengths from 1.0 per cent longer than standard pitch to 2.0 per cent shorter than standard pitch, as shown in Fig. 2. Since we were thinking of shrinkage as a positive quantity, the points on the scale corresponding to lengths of film greater than the standard were marked as "negative" shrinkages, and points corresponding to lengths of film less than the standard were marked as "positive." Thus, when the pointer stands at, for example, the line marked *.5*, this signifies that the film being measured is one-half of one per cent shorter than the standard pitch.

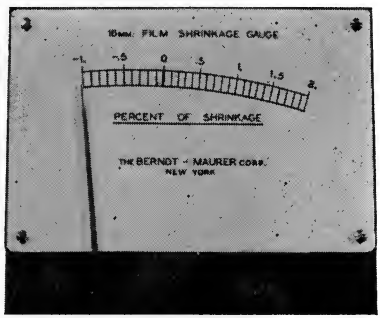

FIG. 2. The scale on which shrinkage readings are indicated.

The pointer of this instrument is relatively long and fragile, and it was considered possible that it might be bent by accident, which would result in false readings. To provide an easy means of checking the accuracy of the gauge we constructed the master test-bar shown in the upper left-hand part of Fig. 1 and in use on the shrinkage gauge in Fig. 3. The space between the stops at the ends of this bar was made 11.750 inches plus or minus 0.001 inch. By placing this test-bar upon the gauge, as shown in Fig. 3, and noting whether or not the pointer reads exactly zero, one can check the accuracy of the instrument in a very few seconds.

With this gauge on a rewind table a series of readings giving the

state of shrinkage throughout a reel of film can be made in a few minutes. The time required to take an individual reading is no longer than the time required to write out the result in a notebook. The readings are reproducible to about two-tenths of the distance between adjacent divisions on the scale, or within about 0.02 per cent, without exercising any unusual care in handling the gauge.

We began using this gauge in October, 1937, taking readings on such pieces of film as passed through our hands in the course of regular work, and noting the results in a small book which was kept with the shrinkage gauge. In the course of a few days we noticed so many in-

FIG. 3. Checking the gauge by means of the test-bar.

teresting facts that we were impelled to begin making a systematic series of readings on two pieces of film that happened to have been processed under identical conditions on the same day. For convenience we shall refer to the manufacturers of these two pieces of film as manufacturer No. 1 and manufacturer No. 2.

The two films were kept on separate reels and were stored in an ordinary filing cabinet in two identical 400-foot cans of the type used for packing film for use in laboratories. Both the films were of the "positive" type used for making sound and picture prints. The cans were kept closed when the film was not being handled, but were not sealed with tape. The lids fitted closely, but not closely enough to exclude air and moisture. In short, conditions of storage corresponded roughly with the conditions under which sound or picture nega

tives are commonly stored. The air of the building was not conditioned, and therefore the humidity varied according to the general state of the weather. Each day for a period of a little more than five months, except on Sundays and holidays, each of these films was rewound, and during the rewinding the shrinkage was measured at six points throughout its length, these points being identified by punch marks in the film outside the length being measured.

The behavior of the two films during this five months' period is shown in Fig. 4. Each point plotted on these curves is the average of the six readings taken on the particular day in question, these six readings invariably agreeing within 0.05 per cent. Therefore we are

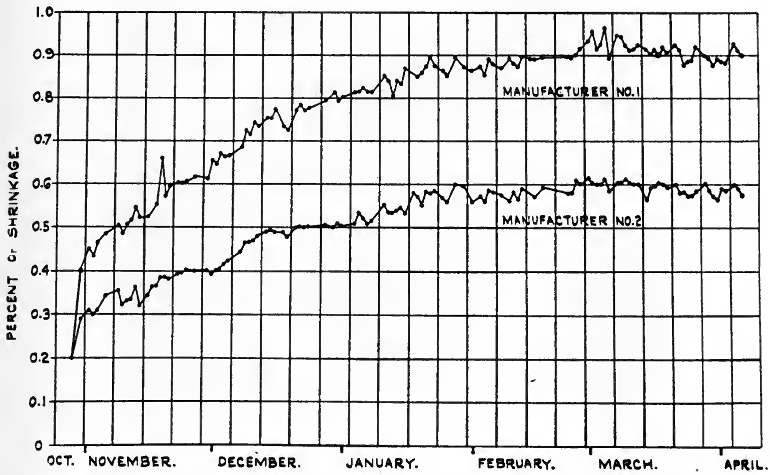

FIG. 4. Shrinkage of two samples of acetate-base film measured daily over a five-month period.

confident in stating that the apparently erratic variations in length indicated on these graphs are real variations and not the result of inaccuracy in the shrinkage gauge. Each vertical line on the graph represents a period of one week; the months are shown at the bottom of the figure.

It will be noted that the two films on the day they were processed both showed a shrinkage of 0.2 per cent. Two days later when the next reading was taken, these shrinkages had increased to 0.4 per cent for the film of manufacturer No. 1, shown in the upper curve, and 0.29 per cent for the film of manufacturer No. 2, shown in the lower curve. Two days later still, the values were 0.45 and 0.31 per cent, respectively. These values are generally representative of

what we have observed in other samples of film of the same manufacturers. It will be noted that the shrinkage that occurred during the first two days after processing was as great as the further shrinkage that occurred during the next two weeks. It will be noted also that, disregarding erratic variations, which we will endeavor to explain later, the shrinkage after the first two days occurred at a practically uniform rate over the following six weeks. After that, the rate of shrinking decreased gradually until after three months the curves seem to indicate that a condition of stability has been reached.

It will be noted that the apparently erratic variations above and below the general trend of the curves show a definite correspondence

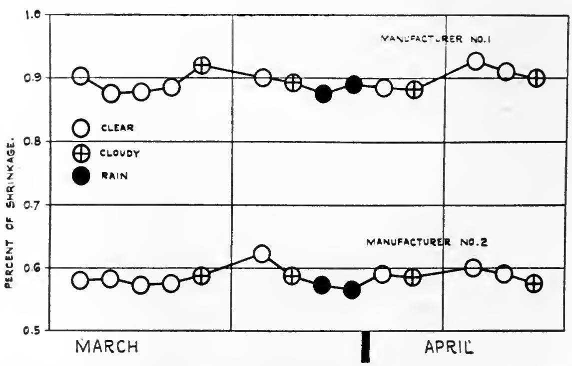

FIG. 5. Enlargement of a section of Fig. 4 to show correlation between shrinkage and weather conditions.

in the two curves. This is especially easy to see during the two weeks following the start of the series of measurements and over the part of the curve after a condition of approximate stability has been reached. We noticed as the series of measurements proceeded that these variations above and below the general trend could be correlated with the changes in weather conditions, and therefore with the general humidity of the air. Fig. 5 has been plotted to show this correlation more clearly. In this figure the character of the circle drawn around each point observed shows the weather prevailing at the time the measurement was made. An open circle indicates fair weather with the sun shining. A circle containing a cross indicates cloudy weather. A circle completely filled in indicates rain. It can be seen from Fig. 5 that the film, even though kept in a closed metal can and exposed directly to the air for only a few minutes each day, is able to absorb

enough moisture during periods of high humidity to expand by as much, in some instances, as 0.04 per cent, and that on the other hand it loses this moisture during periods of lower humidity within as short a period as two days during which it is not handled at all. Appreciable absorption or loss of moisture does not occur during the time required to take the readings, as is proved by the fact that the readings on any given day are consistent from one end of the film to the other.

While the film is able to take up and lose moisture in this way if it is kept in an unsealed can, we have found that a strip of ordinary

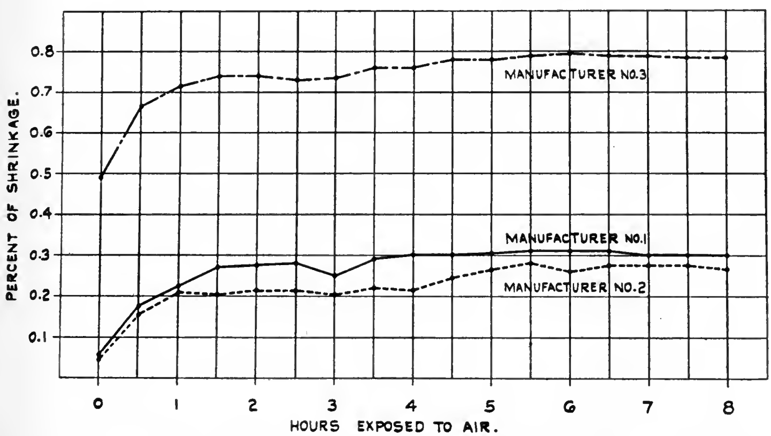

FIG. 6. Shrinkage of three samples of fresh raw stock freely exposed to air.

adhesive tape around the joint of the can seals it very effectively. A roll of processed film placed in the ordinary 400-foot can and sealed in this way will shrink less than 0.1 per cent over several weeks. The same conclusion may be drawn from the behavior of raw stock, which, as we shall show, shrinks very rapidly when freely exposed to the air, but shows not more than 0.15 per cent change in length even when kept in storage for several months.

Fig. 6 shows what happens when strips of raw stock freshly taken from the original package are hung up so as to be exposed to the air on both sides. The vertical lines in this figure represent half-hour intervals, the entire experiment extending over eight hours. The films of manufacturer No. 1 and manufacturer No. 2 were from fresh stock, and showed a shrinkage value of the order of 0.05 per cent

when first taken from their cans. The strips were not taken from the very outside of the roll but from a point about one-quarter of an inch in. The sample from manufacturer No. 3 had been in stock for about two months, and therefore it is perhaps not fair to compare it with the other two samples, though the results are in accord with our other observations in connection with the stock of manufacturer No. 3. It will be noted that each of the samples underwent a shrinkage of the

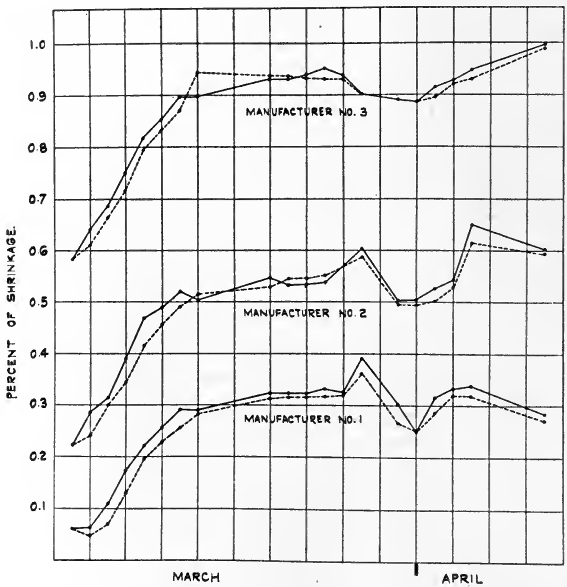

FIG. 7. Shrinkage of three samples of film as affected by use on a projector.

general order of 0.2 per cent within the first hour and a half, and that thereafter the shrinkage is much slower. The day on which this experiment was made was rather humid, and for that reason the total shrinkage in the curves of the 8-hour period is not as great as we should ordinarily expect on the basis of other observations.

Thus far our experiments were directed principally toward determining what may be expected to happen to negative films under the conditions of storage and use for printing in film laboratories. When we decided to present this material in the form of a paper before the Society it seemed desirable to acquire some information about the

behavior of prints as used on projectors. For that purpose we made up a reel consisting of three prints of the same subject on the three types of raw stock, all the prints being processed at the same time. Immediately after processing we measured the shrinkages at several points in each section of the film, and thereafter for a period of two weeks we projected the film twice daily on a projector having a 1000-watt lamp operated at 95 per cent of its rated voltage. The series of measurements was repeated before and after each running of the film on the projector. The results are shown in Fig. 7, in which the broken lines pass through the points measured before running the film through the projector and the solid lines pass through the points measured after projection. It may be noted that the film shrinks unmistakably during each projection and in most cases does not reabsorb enough moisture to regain its earlier length before the next time it is projected. However, these curves do display in a striking fashion the effect of three successive days of heavy fog and drizzling rain, which occurred late in March. The moisture in this case was absorbed by the film in some instances so rapidly as to cancel the ordinary drying effect of the heat of the projector lamp.

In the test shown in Fig. 7 the films of manufacturer No. 2 and manufacturer No. 3 behaved as would have been expected from our previous observations, but the film of manufacturer No. 1 shows a radical departure from its previously observed performance. On the basis of all previous observations we should have expected the curve for manufacturer No. 1 to lie between the curves for manufacturer No. 2 and manufacturer No 3, but on the contrary we find that the film of manufacturer No. 1 here shows a much lower value of shrinkage, and even after repeated passages through the projector has reached a shrinkage of only 0.3 per cent, a value comparable to the shrinkages observed in nitrate-base films and one that would ordinarily be reached within a few hours after processing. We do not know whether to attribute this to some factor that escaped our attention in the handling of the three films or to a change in the nature of the film-base itself, but we have not at any other time observed a sample that showed as low a shrinkage value as this particular sample. If the change in behavior is due to a change in the nature of the stock, it is to be hoped that this manufacturer will continue to supply stock having these characteristics.

In addition to these more or less systematic studies of the behavior of films under specified conditions, we have made many ran-

dom measurements of films processed at various times and handled under various conditions. These measurements serve only to call attention to the great complexity of the problem presented by film shrinkage. We have been unable to arrive at any general conclusions as to the effect of processing conditions, since films processed in different laboratories—some by the rack-and-tank method and some by automatic machine—all measure about the same length after they have been in storage for several months. Films that have been stored in unsealed tin cans show no markedly less shrinkage than films stored in cardboard containers. At one time we felt that we were justified in assigning a characteristic value of shrinkage of 0.5 per cent to the film of manufacturer No. 2, 0.7 per cent to the film of manufacturer No. 1, and 0.9 per cent to the film of manufacturer No. 3 under the conditions of our observations. Recent behavior of these film stocks, however, does not justify our making these generalizations.

The value of ultimate shrinkage is of considerable importance, since it affects the design of sprockets wherever used. The bearing surface diameter of a hold-back sprocket is directly determined by the maximum shrinkage to be accommodated, and the thickness necessary at the base of the tooth of any sprocket is determined by the maximum shrinkage, the minimum shrinkage, and the number of teeth in mesh. In our stock of old films, some of which are as old as six years, we have found only one film that was shrunk more than 1.25 per cent. That was on the stock of manufacturer No. 1 and showed a shrinkage of 1.4 per cent. It was about five years old. On the other hand, films belonging to film libraries on which we have been able to take measurements sometimes showed shrinkages as high as 1.6 per cent.

It is possible that all our measurements are profoundly influenced by the fact that they were made in New York City, where the average humidity is considerably greater than it is in other parts of the United States. In view of the direct evidence that we have presented, that moisture absorption can cause an actual lengthening of the stock, we feel that our results as to the ultimate degree of shrinkage are of little value except as applying strictly to New York City conditions.

It is clear that we have only scratched the surface of a very large and complicated problem. The most casual reflection will suggest a large number of experiments that might be tried to determine the influence of such factors as humidity, surface treatment of the film (as by anti-scratch processes), temperature of storage, *etc.*

One fact we feel has been definitely revealed by these studies. Acetate film base is not a definite product having definite physical constants; its properties can be made to vary over a wide range by different methods of manufacture. We feel that with further experimentation on the part of the manufacturers there is a possibility that safety films may be produced, at least for record purposes and in general for all applications where permanence is desired, having shrinkage properties comparable to those of nitrate-base film.

We have made no comparisons of different film stocks on the basis of strength, flexibility, or any physical properties other than shrinkage. Such comparisons as we have made between the stocks of different manufacturers relate only to the one point of shrinkage behavior. We hope that the results that have been presented here will prove sufficiently interesting to stimulate others to undertake similar studies and to publish their results.

DISCUSSION

MR. BRADLEY: The subject of this paper is of great interest to the National Archives and the National Bureau of Standards. There is a project at the Bureau of Standards that has been going on for about three years under the general title of "Reproduction of Records," but actually it has turned out to be a consideration of preservation of records, and one of the items considered was the shrinkage of film.

Mr. Maurer's device for measuring the shrinkage is a distinct contribution. The results of our own studies, in which shrinkage was observed under controlled predetermined humidity, were published in the December, 1937, *Journal of Research of the National Bureau of Standards.* We found that the film shrinks very rapidly in the first ten days in ovens where the humidity is under control. We are now trying to determine the percentage of shrinkage in aerial-mapping film, where the accuracy must be very great to prevent ground distortion. A very small shrinkage of an aerial map may produce distortion equivalent to as much as sixteen feet on the ground, depending upon the elevation of the camera at the time the exposure was made.

Mr. Maurer stated that on three rainy days the moisture content of the film rose very rapidly. Did the studies include measurement of the restoration of moisture to the film?

MR. MAURER: No, they did not. We only infer that moisture was taken up because of the very definite correlation between shrinkage and state of the weather.

MR. BRADLEY: Would it be an advantage to measure it?

MR. MAURER: I believe that it would. However, we do not have facilities for making such measurements.

MR. BRADLEY: We have developed a technic for restoring the moisture content in film. It consists in rewinding the film slowly, through what we call a rehumidifier, and blowing moisture across the surface of the film. If the film is

closely wound in rolls, as many as six months may be required for the moisture to penetrate to the interior of the roll.

MR. KELLOGG: I do not suppose that you have made measurements of film from which the gelatin has been removed. The question does not enter, so far as I can see, into the practical problem that you are investigating, but it might be of interest to be able to separate the effect of moisture upon the gelatin from the effect upon the base. There are some problems in connection with which we are interested in the action of moisture on the base alone.

MR. MAURER: No measurements of that sort have been made. However, in the piece of film that was projected at regular intervals we provided areas that were transparent and other areas were exposed to complete opacity so far as was possible, and care was taken in making the measurements to include both the transparent and the completely opaque areas. We found no consistent difference between the shrinkage behaviors of these two sections of the film. We expected to find such a difference, because the black film would presumably absorb heat during projection more completely than the transparent film, but to our surprise we found no difference.

MR. FRIEDL: Several years ago some shrinkage measurements were made in an exchange in New York on 35-mm. film, checking the films as they went out and as they were returned after being shown in several theaters, plotting the shrinkage against age and use, and keeping records of the weather during that period. Our observations, I should say, were very similar to Mr. Maurer's with respect to the stretching of the film on wet days.

MR. GRIFFIN: I noticed that your shrinkage measurements were longitudinal shrinkages. In such measurements as I have made, on 35-mm. nitrate-base stock, I have found that the lateral shrinkage is far greater than the longitudinal. I am wondering whether that is so in the case of acetate-base stock, and whether you used the longitudinal shrinkage figures in computing the figures you gave for the placement of the sound-track.

MR. MAURER: The answer is yes. We used the longitudinal shrinkage figures. We have not made direct measurements of the lateral shrinkage of 16-mm. film. A number of years ago I had occasion to do a piece of work that extended over about a year, that showed at that time very accurate agreement between longitudinal and lateral shrinkage of, as it happened, acetate-base films. However, those films were not subjected to the conditions encountered when a film is projected, and therefore the result arrived at then, that the longitudinal and lateral shrinkages were the same, is not valid as applying to the conditions of actual use of 16-mm. films. Mr. Griffin has raised a very important question and one on which we shall endeavor to throw some light if we can devise a satisfactory method of making the measurements.

MR. MITCHELL: Has anybody investigated what might be described as the "warping" of 16-mm. sound-film, caused by the film having sprocket-holes on one side and not on the other? It is found more particularly in 8-mm. film, but also in 16-mm., that the shrinkage is not the same along the two sides. Greater shoe service between the picture and the sound area takes care of any very slight wrinkling that may occur that would affect the sound quality, and would help to keep the film down and within the depth of focus of the scanning lens.

MR. DEPUE: I had occasion to try to make some reduction prints from a 60-

mm. film that I had in 1897, and I had a sprocket-wheel that fitted the film at that time. When I came to make the reduction I looked up the old sprocket-wheel and found that the shrinkage sidewise at the perforations was more than $^1/_{32}$ inch, not by accurate measurement, but rough observation. Longitudinally the sprockets seemed to fit all right over the four or five teeth the film engaged. The film was a nitrate negative film, kept in ordinary storage.

MR. IVES: V. B. Sease in a paper published in the *Transactions* of the Society ("Moisture in Motion Picture Film," **12,** No. 34, p. 390, April, 1928) showed some interesting effects of fluctuating moisture content upon the dimensions of cellulosic films. More recently, Weber and Hill ("The Care of Slide-Films and Motion Picture Films in Libraries," *J. Soc. Mot. Pict. Eng.*, **XXVII,** Dec., 1936, p. 691) studied the interrelations of shrinkage, moisture content of film, and humidity of surrounding atmosphere for the safety type of film. In another paper published about the same time by the same authors ("Stability of Motion Picture Films as Determined by Accelerated Aging," *J. Soc. Mot. Pict. Eng.*, **XXVII,** Dec., 1936, p. 677) safety-film was reported to be stable and lasting in accelerated aging tests. While their judgments were based upon tests of chemical and mechanical properties, their conclusions are of interest in connection with the topics under discussion. Davis and Stovall ("Dimensional Changes in Aerial Photographic Films and Papers," Research Paper *1051, J. of Research Nat. Bur. of Standards,* **19,** Dec., 1937, p. 613) have commented favorably upon the shrinkage characteristics of some samples of acetate film tested in comparison with films of the type used for aerial mapping.

PROCESSING OF ULTRAVIOLET RECORDINGS ON PANCHROMATIC FILMS*

J. O. BAKER**

Summary.—*The necessity in newsreel work of making the original sound recording on panchromatic film has always meant a serious sacrifice in quality and ground-noise ratio, as compared with results that can be attained when sound is recorded on a separate film. While ultraviolet recording materially increases fidelity of response, with panchromatic as well as with standard sound negative film, the low contrast and high base fog of panchromatic film processed for negative picture development produce noise and considerable reduction in volume range.*

The track density on the panchromatic film is rather low, of the order of 1.0 to 1.2, when recorded with a practical optical system for a single-film system. When this track is printed on commercial release print stock the dense portion of the negative track will print through, producing a fog density in the clear portion of the printed track. This fog in the clear portion tends to produce noise and reduces the volume range. When the panchromatic negative and print are processed in accordance with commercial practice, the reduction in volume range is of the order of 6 db.

Printing panchromatic negative upon a high-contrast emulsion improves both the noise and volume range. Since the release prints must be on standard picture positive stock and not on high-contrast film, it is proposed to make a master positive on high-contrast emulsion and to re-record from this to a standard sound negative, which would be used in the ordinary way to make the release prints. An improvement in release print ground-noise of 8 to 12 db. is obtained by this method, and the volume range is increased by 6 db. Briefly, the proposed method is a means for increasing the density contrast of the final release print track when the original is recorded on panchromatic film.

It has long been known that emulsions with fine grain and high contrast gave superior results for variable-width sound recording. The investigations made by Hoxie of the General Electric Company in 1921 led to the adoption of positive types of emulsion for this purpose; however, in single-film systems, where the picture and sound are recorded simultaneously on the same film, the sound must be subordinated to the picture. The coarse grain of panchromatic emulsion together with the method of picture processing for an over-

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** RCA Manufacturing Co., Camden, N. J.

all gamma of unity produces sound-tracks of poorer quality than can be obtained with fine-grain recording emulsions.

This paper describes the results that can be obtained when variable-width sound-tracks are recorded with ultraviolet light on panchromatic film and printed with ultraviolet light on motion picture positive film and processed in accordance with the commercial technic for motion pictures, as well as the employment of a high-contrast emulsion for use as a master positive. Image definition of panchromatic emulsion is somewhat poorer than that of positive emulsions.

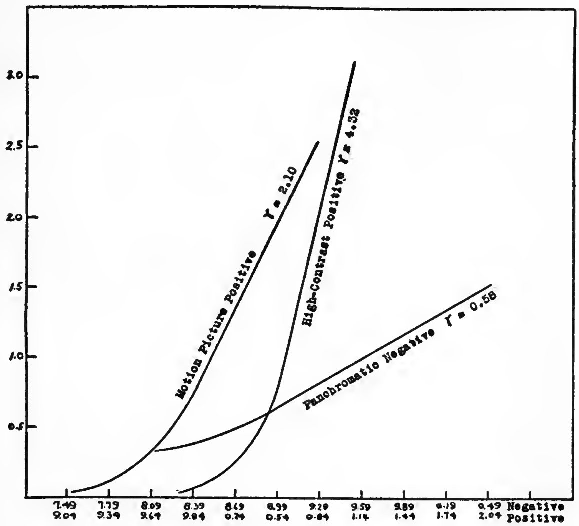

FIG. 1. Sensitometric characteristics for sound recording: Panchromatic in *D76*, $8^1/_2$ min., 60°F; motion picture positive in *D16*, $4^1/_2$ min., 65°F; high-contrast positive in "Dev. A," $13^1/_2$ min., 65°F.

The ultraviolet filter is used in the recording to reduce the image spread and to improve the response at the higher frequencies. This permits recording at a higher track density, but limits the maximum density attainable due to the restriction of the recorder light to a narrow spectral band.

With white-light recording on panchromatic film, the best results were attained with equal negative and print densities, of approximately 0.80. These were the conditions that most nearly fitted the requirements for minimum image distortion in motion picture posi-

tives. Ultraviolet recording reduces the image spread in the negative thereby permitting a higher density in the recorder track.

The base or fog density of panchromatic film is approximately 0.34, and with a recorded track density of 1 or greater, the difference in transmission through the dense and clear portions of the track is considerably reduced. The printer light will, therefore, penetrate the clear portion and produce an exposure on the print which for a

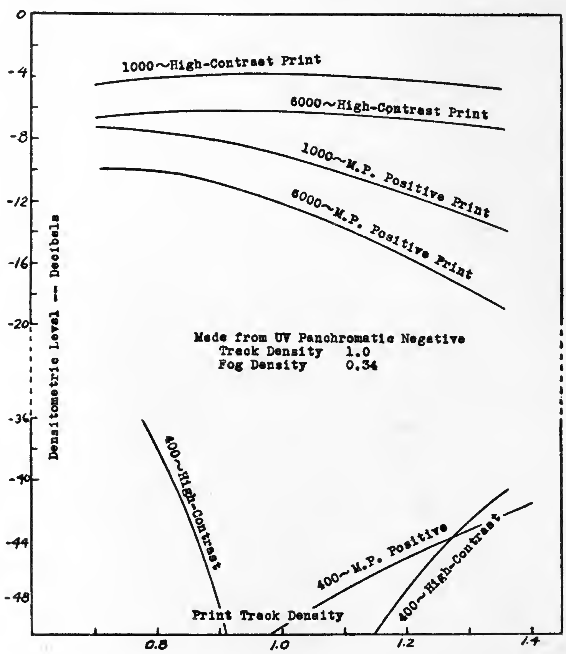

FIG. 2(*A*). Panchromatic sound recording: cross-modulation characteristics.

perfect track should be unexposed. This exposure or fogging of the clear portion of the positive track results in reduced output as well as increased noise.

By the use of a high-contrast emulsion for printing a master positive for use in re-recording, the fog density in the clear portion will be materially reduced. A more complete explanation will be given later in this paper.

Use is made here of "densitometric level" for the purpose of com-

paring the results obtained in the two methods of printing. The zero reference of densitometric level is chosen as that of an ideal film in which the clear portions are completely transparent, the dense portions completely opaque, and the recorded track is equal in width to the scanning slit. A perfect sound-track with the present standardized dimensions for width of recorded track and scanning-slit width would have a densitometric level of −0.9 db.

The procedure for determining the processing conditions has been described previously in the JOURNAL.[1]

Procedure.—Modulated recordings were made on panchromatic film, using the standard ultraviolet optical system on an *R-4* type of

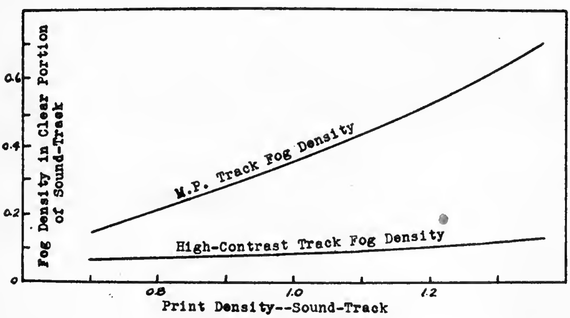

FIG. 2(*B*). Panchromatic sound recording: fogging of positive track.

recorder, but substituting a 2-mm. No. *597* Corning filter, for the 30-mil No. *584* filter.

The recordings consisted of 1000-, 6000-, and 6000-cycles modulated with 400-cycles, each of sufficient length for making output measurements. A frequency of 6000 cycles was used in this case since this is the cut-off frequency of most single-film systems for newsreel work. The film was then processed for picture technic by developing the panchromatic film in *D-76* for $8^1/_2$ minutes at 62°F, producing a gamma of 0.58. The negative was then printed on the non-slip printer upon motion picture positive and processed for picture technic by developing in *D-16* for $4^1/_2$ minutes at 65°F, giving a gamma of 2.10.

The high-contrast prints were also made on the non-slip printer using a high-contrast emulsion and developing in a high-contrast

developer, Developer A,[2] for $13^1/_2$ minutes at 65°F, producing a gamma of 3.95.

A frequency recording ranging from 1 to 10,000 cycles was made also on the panchromatic film and printed upon both the motion picture positive and high-contrast positive with their respective processings for determining the high-frequency loss.

An unmodulated track of various widths ranging from 5 to 36 mils was recorded on panchromatic film and printed upon both types of positives for the purpose of making the ground-noise measurements.

All output measurements were made on a calibrated film phonograph and were corrected for amplifier and reproducer slit losses. All measurements are expressed in terms of the densitometric level.

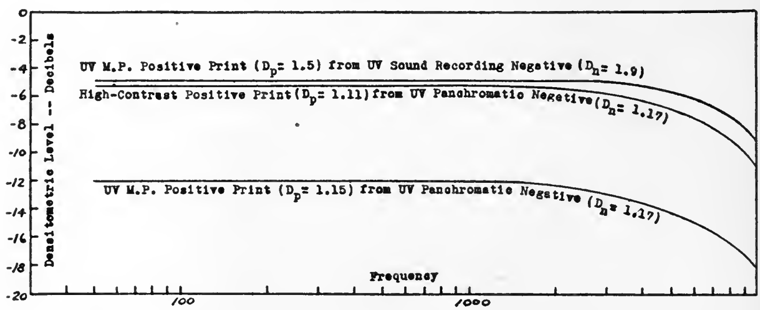

FIG. 3. Panchromatic sound recording: film loss characteristics.

Panchromatic Negative.—While a number of negative densities were recorded, the one with a track density of 1.0 was chosen for showing the relative levels and image-spread cancellation, since this density will probably be the average that can be obtained in practice.

For the film-loss characteristics and ground-noise measurements, slightly higher densities were used. The sensitometric curve is shown in Fig. 1.

Motion Picture Positive.—The motion picture positive stock was printed to various densities for determining the image-spread cancellation and relative outputs.

The sensitometric curve for the motion picture positive is shown in Fig. 1 and the 1000- and 6000-cycle output measurements together with the 400-cycle output are shown in Fig. 2(A). Fig. 2(B) shows how the fogging of the clear portion of the printed track varies with the printed track density.

The print of film-loss characteristics was made at a density of 1.11, and the results are shown in Fig. 3. The print for the ground-noise characteristics was made at a density of 1.23, and results are shown in Fig. 4.

In the latter two cases, the print density was made to equal that of the negative density as nearly as possible. All motion picture positive prints were made with an ultraviolet filter in the printer.

High-Contrast Positive.—The high-contrast positives were printed on the non-slip printer with white light and the various results obtained are shown in the corresponding figures mentioned above for the motion picture positive.

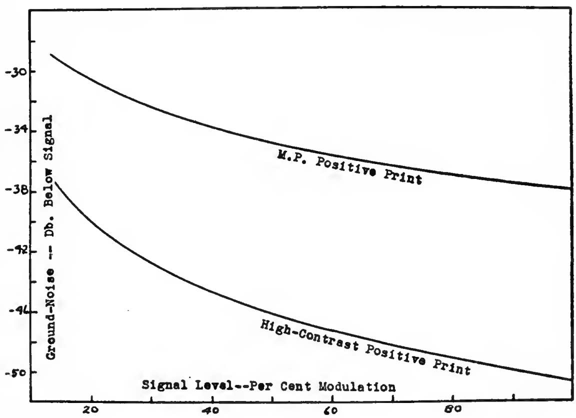

FIG. 4. Panchromatic sound recording: ground-noise characteristics.

Discussion.—In Fig. 2 the motion picture positive print for a density of 1 is approximately $6^1/_2$ db. below the output of a print made from an ultraviolet recording on sound recording positive while the output of the high-contrast emulsion is only $1^1/_2$ db. lower than that attainable with a print made from a negative recorded on standard sound recording positive emulsion. The fog density for the motion picture positive at a track density of 1 is 0.35, while that of the high-contrast positive is only 0.08.

Cancellation of image spread occurs over a rather wide range for the high-contrast emulsion, ranging from approximately 0.09 to 1.2, while that of the motion picture positive ranges from a print density of 1.0 downward.

The film-loss characteristic of Fig. 3 shows a low-frequency output for the motion picture positive print of only -12 db. while the high-contrast low-frequency level is -5 db. The 10,000-cycle output for the motion picture positive is 2 db. less than that for the standard sound recording, while the output for the high-contrast positive at 10,000 cycles is only $^1/_2$ db. less. The ground-noise for the high-contrast is considerably lower than that for the motion picture positive, being -19 db. lower for low values of modulation.

The use of an inverted mask in the recorder optical system for recording a positive sound-track provides a negative sound-track when

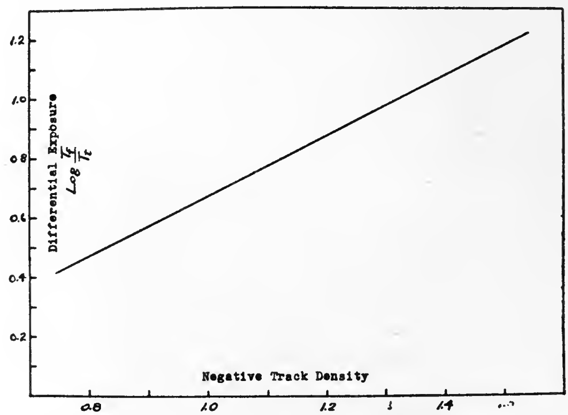

FIG. 5. Panchromatic sound recording: differential exposure through track and fog densities of negative (fog density = 0.34).

printed upon the high-contrast emulsion, which could then be used as a negative for printing directly to the motion picture prints.

Fig. 5 provides a ready means for determining the track fog density of a print for any value of recorded track density. The differential exposure when applied to the base line of the sensitometric curves will spread between the print track density (which should be the same as the negative track density) and the track fog density.

Conclusions.—Since the fog density of panchromatic film is approximately 0.34 and the maximum negative track density attainable is of the order of 0.8 to 1.1, the difference in transmission through the dense and clear portions of the track is quite small. Printing this track upon positive film results in fogging the clear portion of the printed

track, thereby introducing noise and reducing volume range. The higher the negative density, the less will be the ground-noise and the reduction in volume range.

When the negative and positive sound-tracks are processed in accordance with picture technic, the print density should be equal to the negative density or slightly less. With a negative track density of 1.0 on the panchromatic film and a print density of 1.0 on motion picture positive, the density of the clear portion of the printed track is approximately 0.35, resulting in a densitometric level for 1000 cycles of −12 db. and a ground-noise level of −28 db. for zero signal and −38 db. for a 100-per cent signal.

Printing this same negative on a high-contrast emulsion for the purpose of making a dupe negative or master positive for re-recording, the density of the clear portion of the track is 0.08, giving a densitometric level of −7 db. and a ground-noise level of −37 db. for zero signal, and −50 db. for a 100-per cent signal.

While satisfactory results can be obtained from an ultraviolet recording on panchromatic film and printing directly to motion picture positive, they are far from ideal. The use of a high-contrast emulsion as an intermediate step provides means for obtaining greater volume range and lower ground-noise. The final release print in either case can not, of course, be as good as recordings made on the finer-grained emulsions.

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[1] BAKER, J. O., AND ROBINSON, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions for Optimal Processing," *J. Soc. Mot. Pict. Eng.*, **XXX** (Jan., 1938), No. 1, p. 3.

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DISCUSSION

MR. FRAYNE: Why was the change made from the *584* to the *597* filter, which has more blue-violet?

MR. SACHTLEBEN: For the reason that the *584* transmitted more red light than the *597*. Of course the red could be reduced somewhat by increasing the thickness of the *584*, but we should have to go up quite a way and suffer a loss in the ultraviolet. We chose the *597* to get rid of the red without such loss.

MR. RICHTER: What is the thickness of the filters?

MR. SACHTLEBEN: The *597* used in the newsreel system is 2 mm. thick. That was the minimum thickness we could use and still eliminate the red.

AN OPTICAL SYSTEM FOR THE REPRODUCTION OF SOUND FROM 35-MM. FILM*

J. H. McLEOD AND F. E. ALTMAN**

Summary.—*An optical system has been designed and tested for use in 35-mm. sound reproducers. It is the slitless type, and gives a scanning image that is 0.001 inch wide when used with an exciter lamp having a coil diameter of 0.055 inch. A toric lens is used to form a curved-line image of the filament of the lamp. This curved image is then re-imaged by a highly corrected objective lens of numerical aperture 0.28. The objective lens has inherent curvature of field, but this curvature is compensated by the curvature of the line-image formed by the toric lens so that the final image is flat. The toric lens also acts as a condenser lens to throw an image of the filament into the objective lens. Careful tests of samples show that the final image is flat, straight, and of uniform width and intensity.*

The purpose of the optical system in a sound reproducer for sound on film is to provide a narrow bright line of light, usually 0.084 inch long and 0.001 inch wide, on the sound-track of the film.

Some of the requirements of the system may be stated briefly as follows:

(*1*) The line image must be of the *proper dimensions.*

(*2*) The image must be as *bright* as possible.

(*3*) No light other than the light in the image should strike the film.

(*4*) The image must be *straight.*

(*5*) The image must be *flat,* so as to be in focus in the plane of the film along the entire length of the image.

(*6*) The image should be of uniform *width* and of uniform *intensity* along its length.

(*7*) In the plane of the film, the image must be at right angles to the direction of motion of the film.

(*8*) Small displacements of the source should not produce changes in the intensity or dimensions of the image.

A great variety of optical systems have been designed from time to time. In general, they fall into three classes: (*1*) The *slit type,* in which an image of the filament of the exciter lamp is formed upon a

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** Eastman Kodak Co., Rochester, N. Y.

narrow physical slit and the slit is then re-imaged by an objective lens upon the sound-track on the film; (*2*) the *condenser projection system*, similar to a lantern-slide projector, in which an objective lens forms an image of the condenser (and anything placed over the condenser) upon the film: a physical slit is accordingly placed over the condenser lens; (*3*) the *slitless type* or so-called apertureless system, in which an image of the filament itself is formed upon the film by one or more lenses.

Of these classes, the first has two serious faults: (*a*) If a coiled filament is used, the illumination along the slit will not be uniform because of the individual turns of the coil; (*b*) the filament must be located very accurately, relatively to the optical system, in order to

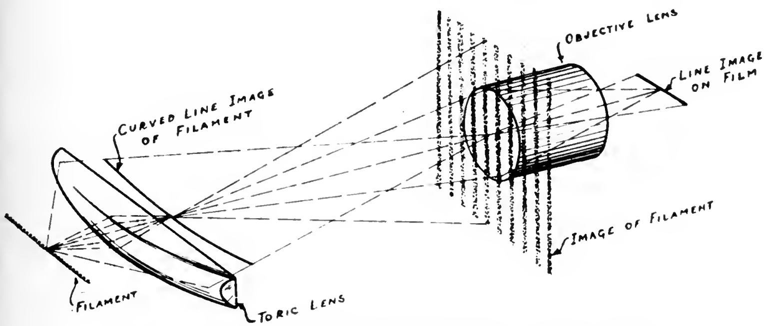

FIG. 1. Idealized perspective view of the optical system.

place the image of the filament exactly upon the slit; otherwise, loss of illumination and microphonics will result.

The second class of optical system may be subject to microphonics resulting from movement of the image of the filament across the objective lens. On the other hand, this class should give very uniform illumination along the length of the scanning image.

The slitless type of optics is superior in its freedom from microphonics. The width of the scanning line, however, is not fixed by the optical system alone, but depends upon the size of the source and the distance of the source from the lens.

An important problem in the design of high-quality sound optics is to obtain a flat scanning image upon the film. This problem arises from the fact that the simpler types of spherical objective lenses have the defect of curvature of field. This defect is in some sys-

tems compensated for by curved slits or by curved virtual images of slits to make the final image flat.

One of the features of the system herein described is the unique method used to obtain a flat field. Another aspect of the system is that it does not belong to any one of the three main classes mentioned, but is a mixture of (*2*) and (*3*).

Fig. 1 illustrates the general idea of the system and Fig. 2 shows elevation and plan views of it. Fig. 2(*B*) illustrates the projection type of sound optics; the elevation view, Fig. 2(*A*), the slitless type. Let us look at the elevation, Fig. 2(*A*). The small cylindrical lens in

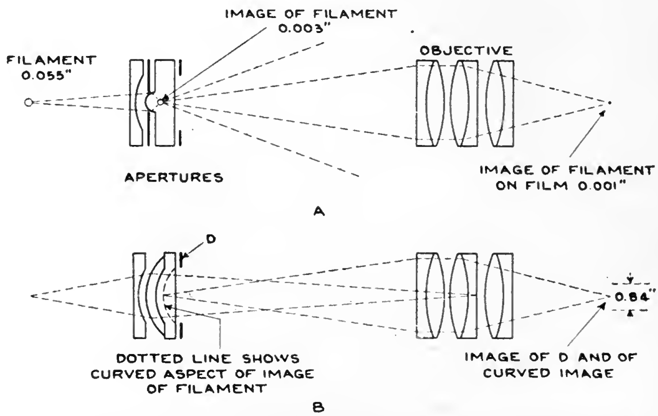

Fig. 2. Sound optics for 35-mm. reproducers: (*A*) elevation view, (*B*) plan view.

the condenser unit images the filament into a line at a reduction of 18.3 times in the short dimension. This line is re-imaged upon the film at a reduction of 3:1 by a high-quality spherical objective. If the diameter of the filament coil is 0.055 inch, the final image is therefore 0.001 inch thick.

A mask covers all of the condenser unit except a narrow strip along the small cylinder. The width of the strip is such as to provide a relative aperture about twice as large as is necessary to fill the objective lens. This allows for a vertical displacement of the filament of about half its diameter, up or down, without affecting the intensity of the light that passes through the objective. Microphonics are thus almost completely eliminated.

Fig. 2(*B*) is a plan view of the optical system. The unique design

of the condenser unit now becomes apparent. It is seen that the small cylinder, shown in cross-section in Fig. 2(*A*), has a curved axis. In this way a toric lens is produced. Its minor radius appears in Fig. 2(*A*) and its major radius in Fig. 2(*B*).

The major radius of the toric lens has two very important purposes: It acts in conjunction with a special window as a condenser lens to throw an enlarged image of the filament into the objective lens; and in addition, it produces a *curved* line image of the filament within the glass of the condenser unit. This curvature of the image is for the purpose of matching the curvature in the object space of the objective lens so that the final image will lie flat upon the film. It so happened that the curvature required for the condenser and for correcting the curvature of field were practically identical.

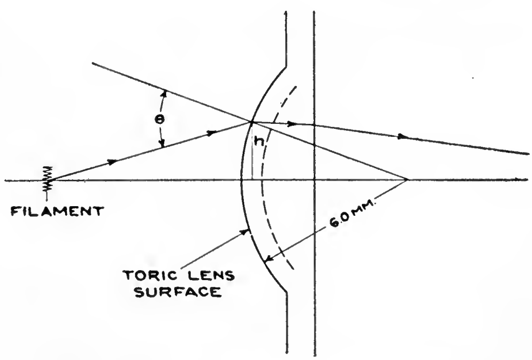

FIG. 3. Path of a ray through a toric lens.

A circular aperture *D* was placed over the condenser unit, as shown in Fig. 2(*B*), to define the length of the scanning image.

A window was placed over the condenser unit to keep dirt away from the surface of the toric lens. In addition, the window is an aspheric lens whose inner surface is shaped to compensate for "spherical" aberration in the condenser aspect of the toric lens.

The objective lens consists of three simple achromatic doublets. The doublet on the object side collimates the light; the other two then bring the parallel beam to a focus upon the film. The lens is very highly corrected, and therefore gives excellent definition in spite of the high working aperture of $f/1.8$, or the numerical aperture of 0.28. Incidentally, the working aperture could be increased to $f/1.5$, if desired.

In order to test the general idea of the optics as outlined above, a toric lens as described was made up. The system gave a very well defined image of great intensity and it lay flat in the plane of the film. One expected defect, however, was apparent, *i. e.*, the width of the image was less at the ends than at the center. An examination of the first curved image formed directly by the toric lens showed that it, too, suffered from a falling off in width at the ends.

The reason for the decrease in width of the line image at its ends was that rays from the lamp that struck the toric lens at points off the axis of the lens system did so at an angle θ, rather than normally (Fig. 3). These rays, therefore, encountered a sharper curve and were brought to a focus at a shorter distance and, therefore, formed a smaller image.

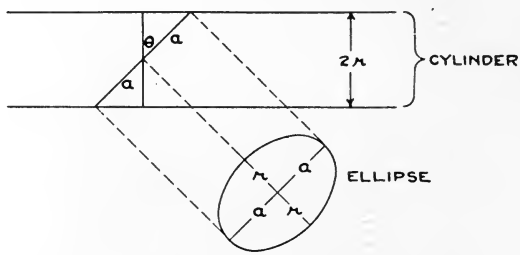

Fig. 4. Section of a cylinder cut by a plane at the angle θ.

The magnitude of the defect can be calculated as follows: The section of a complete cylinder cut by a plane is an ellipse (Fig. 4). Let the radius of the cylinder be r. Then the minor axis of the ellipse will be r. Let the major axis of the ellipse be a. Then $a = r/\cos\theta$. We are interested in the radius of curvature of the ellipse at the end of the major axis because that is the curvature that determines the power of the cylindrical lens for rays hitting it at the angle θ. It can be shown from geometry that the radius of curvature R at the end of the major axis of an ellipse equals r^2/a. Substituting for a, we get $R = r\cos\theta$. Thus, the effective radius of the toric lens decreases as $\cos\theta$, and, therefore, the size of the image formed will be proportional to $\cos\theta$. This was found to be true experimentally in the case of the toric lens mentioned above.

A new toric lens was then designed in which the minor axis was

made greater in the proportion $1/\cos \theta$ at points off the axis of the system. Fig. 5 shows the appearance of the finished lens.

Three of these completed lenses were mounted in three finished optical systems and were given very careful tests.

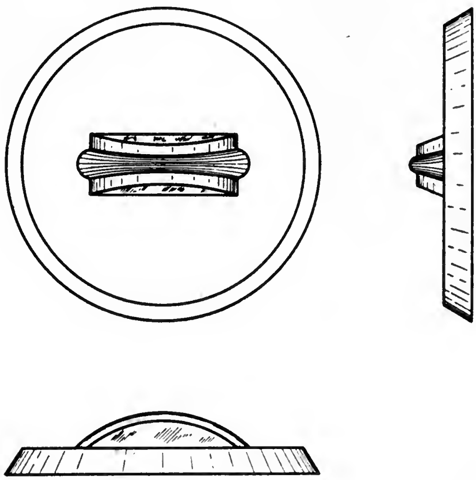

FIG. 5. The toric lens.

The optical system being tested was mounted in a jig along with a 10-volt, 5-ampere exciter lamp placed at the proper position relative to the optics. The jig was then placed upon a travelling microscope, and the microscope was focused upon the scanning image. The

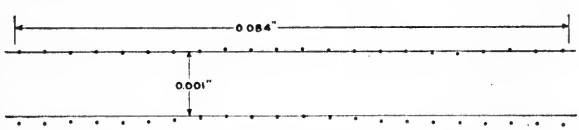

FIG. 6. Enlarged plot of scanning image.

microscope had a 4-mm. objective in it so that a magnification of about $400X$ was produced. A micrometer eye-piece was used in the microscope to measure the position of the edges of the image and hence the width of the scanning line. The microscope could be moved sidewise to bring into view any desired part of the scanning image.

The image was found to be flat to such a high degree that it was scarcely possible to detect any loss of sharpness as the microscope was

moved from end to end of the image. With the micrometer eye-piece measurements were made of the positions of the two edges of the image, at twenty-two positions distributed equally along the length of the image. Fig. 6 is a plot of these measurements taken of one of the systems; the straight lines were drawn 0.001 inch apart. Inspection of Fig. 6 shows that the image was straight and of uniform width to a high degree of accuracy. The other two systems had images substantially the same as that given in Fig. 6. The average widths of the images formed by the three systems were 0.00107 inch, 0.00104 inch, and 0.00107 inch, respectively, and the lengths were 0.0847 inch, 0.0852 inch, and 0.0847 inch. The correct length is 0.084 ±

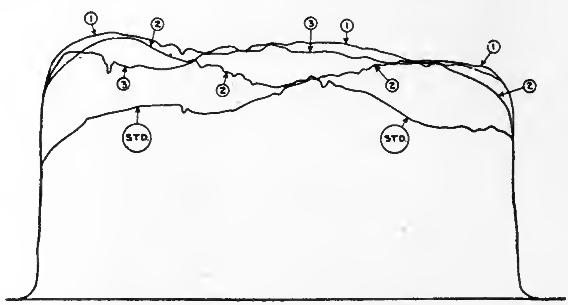

Fig. 7. Microdensitometer traces of intensities along the scanning images produced by sound optical systems. The curves marked *1*, *2*, and *3* are for three sample systems of the type described. The one marked *STD* is for a well known system in general use.

0.001 inch. The width of the image can, of course, be adjusted by placing the filament of the lamp closer to or farther from the optical system. For example, if the filament were moved 1 mm. farther from the optics, the size of the final image would be reduced by about 7 per cent. A microdensitometer trace showed that the uniformity of illumination remained the same when this change was made.

The final test was to place the jig containing the optical system in a microdensitometer so that an enlarged image of the scanning image was thrown across the slit of the microdensitometer. When the stage of the microdensitometer was moved, it carried the optical system with it, and the image moved across the slit, and thus a record could be made of the intensity of the scanning image from one end of the scanning image to the other. A standard optical system of a well known make was tested in a similar way. An 8-mm. objective was

used in the microdensitometer instead of the usual 16-mm. one so as to be certain that all of the cone of light from a point of the scanning image would be transmitted to the photocell.

The curves of Fig. 7 give the results. It will be noted that the new systems give about 35 per cent more light than the standard system, as indicated by the average heights of the curves. Of this amount, 23.5 per cent would be accounted for by the use of an $f/1.8$ objective instead of the $f/2.0$ objective used in the standard optics. Another 6 per cent would result from the fact that the width of the scanning images is 0.00106 inch wide instead of 0.0010 inch. In addition, it was noticed that the objectives in the three new optics were almost completely filled with light because of the nature of the design, whereas in the standard the objective was not completely filled.

The other factor to be noticed is the variation in the height of the curves from one end to the other. Measurements give a variation of ± 11, ± 13, and ± 9 per cent for the three new systems, and ± 17 per cent for the standard one.

To sum up, we now list the following advantages for the new optics: (*a*) Considerable tolerance in the position of the filament of the exciter lamp is permissible, *e. g.*, ± 0.020 inch in any direction; (*b*) freedom from microphonics; (*c*) excellent definition; (*d*) an extremely flat and straight image; (*e*) good uniformity of light-intensity along the length of the image and a high total intensity; and (*f*) comparatively low cost.

DISCUSSION

MR. ALBERSHEIM: I should like to warn against being too optimistic with regard to lamp filament vibrations in such a system. While vertical vibration of the filament in this type of optic will not produce microphonic noise, it will shift the scanning-beam image up and down in a direction opposite to the filament vibration and therefore will modulate the signal frequency, producing flutter. Therefore, it is better to watch for good cushioning of the lamp despite the absence of direct microphonics.

MR. ALTMAN: It is true that there would be a slight motion of the scanning-beam in the film-gate with an extreme vertical vibration of the filament. However, since the total optical reduction is about fifty to one, such motion should not be serious.

MR. CARLSON: Mr. Altman mentioned the fact that the height of the scanning-beam could be reduced by moving the source either nearer to or farther from the collecting lens. It might be well to add that the height of the scanning-beam can be varied also by selecting a lamp having a coil diameter different from the one referred to in the paper.

MR. ALTMAN: Mr. McLeod examined the uniformity of intensity with some

longitudinal motion of the source. He moved the source enough to produce a 6 to 8 per cent change in the height of the scanning image. No appreciable change in the uniformity of illumination was noted.

Mr. Kellogg: Have you any figures, either calculated or measured, that show the tolerance of filament height, as limited by the tendency to produce a curved image on a film if it gets much below a normal level?

Mr. Altman: We had not anticipated a departure from the ideal axial position, which I imagine is what you mean would cause a curvature. There was a suggestion of slight curvature in the findings of Mr. McLeod. Whether or not that was due to a slight defect in the pressing or caused by some displacement I would not know.

Mr. Cook: How do you form a lens as complicated as that?

Mr. Altman: It is a molded lens. The die is polished so that an optical surface results. The making of the die can be visualized by imagining a piano wire wrapped around a small cylinder, and this used as a pattern for the die. It was found necessary to vary the diameter of the piano wire along its length to secure uniform width of image of the filament.

Mr. Friedl: Do you find in this system any secondary images, caused by reflection within the glass of the exciter lamp?

Mr. Altman: There is in the system a mask. The focal length of the anamorphote in its strong meridian is about 0.8 mm., and since we wish to flood the imaging objective with light at about $f/5.4$, you would have to have an aperture in that meridian of only 0.8/5.4, which would be about 0.15 mm. That does require, then, a small mask with a slit 0.15 or 0.20 mm. along the strong meridian of the pressing. The diffraction, or scattered light, from the edges of the mask might cause some secondary image.

Mr. McLeod: If the axis of the exciter lamp is perpendicular to the axis of the optical system, as it is in practice, the reflected image in the glass is directly behind the filament and is hidden by the filament. However, it has been found that if the lamp is displaced a considerable distance above or below its proper position, a weak image is formed above or below the main image. The displacement to produce this, however, has to be greater than is normally encountered.

Mr. Friedl: Do you find that so-called azimuth variation is more critical in this type of system? In the system with the mechanical slit, the slit is held in fixed relation with respect to the optical scanning beam, and that determines the azimuth with respect to the position of the filament; whereas in this case, I am wondering whether or not the tilt of the filament axis may not introduce an azimuth loss or scanning loss, as a function of the tilt.

Mr. Altman: Each and every point on the filament is imaged as a line on the film, and the azimuth of the line is determined solely by the azimuth of the pressing or cylinder. The total image on the film is the net effect of all the lines imaged from all the points on the filament.

If the filament is tilted it will not change in the slightest degree the azimuth of the final image but will increase somewhat the height of the image.

Mr. Friedl: That is the same effect as is due to misalignment in a mechanical system. The effect of the azimuth is the same as having a slit as wide as the two corners.

Mr. Altman: That is true.

MR. FRIEDL: And the filament sag would cause a very similar effect.

MR. ALTMAN: That is right. The particular lamp we have suggested is well suited because it has a rather large diameter of filament and a rather short length. A given angular tip therefore produces less spread of the image than would a similar angular tip with a long slender filament.

MR. KELLOGG: I believe that I see the answer to the question I asked a few minutes ago in reference to the effect of changing the lamp height; the conditions of focal length and focus position that give you a beam of uniform width are identical with the conditions for relative immunity to curvature resulting from change in lamp height.

MR. MCLEOD: We agree that Mr. Kellogg's remark is an exact statement of the truth regarding the absence of curvature when the height of the lamp is changed. The toric lens is designed to give a line image of uniform width. That means that the magnification is the same at the center as at the ends of the line. Since the magnification is the same, a given displacement of the source up or down will cause a displacement of the line up or down that will be the same at the center as at the ends. In other words, the plane of the curved image (which is horizontal) will remain parallel to itself if the source is moved up or down. It is true that as viewed from the objective the curved line will appear straight when the plane of the curve passes through the center of the objective, but when the plane moves above or below the center of the objective lens the curved line will appear to be slightly curved. A slightly curved image would be produced. However, since the vertical displacement of the curved image is $^1/_{18}$ the displacement of the source, and this in turn is reduced to $^1/_3$ size, the curvature in the final image on the film would be too small to measure.

PUSH-PULL RECORDING WITH THE LIGHT-VALVE*

J. G. FRAYNE AND H. C. SILENT**

Summary.—*Push-pull recording on film is accomplished by means of a double light-valve having four ribbons. Distortions introduced by the recording medium that are represented by second-order harmonics balance out in reproducing, as do also the frequencies introduced by the action of the noise-reduction system. As a result, push-pull recording not only eliminates certain defects of conventional recording, but permits the application of new technics that allow further extension of the volume range and improvement in the naturalness in the final product.*

The use of the push-pull principle in transmission systems is well known as a means by which certain distortions introduced by the transmitting devices are balanced out. These are distortions caused by the introduction of second-order harmonics and effects that occur simultaneously in both sides of the push-pull system, but not in push-pull relationship. This principle has been applied to recording sound on film by recording two adjacent tracks 180 degrees out of phase with each other.[1] The two tracks are scanned in reproducing so that the light transmitted through the individual tracks falls separately upon two photoelectric surfaces connected to amplifiers in such manner that the resultant voltage developed is proportional to the difference in transmission of the two tracks. In this manner the push-pull principle is employed to balance out certain distortions that otherwise would be reproduced. These are referred to in the following as "unwanted components."

In order to understand better the value of push-pull recording, we shall classify here the various sources of distortion ordinarily encountered in conventional recording. The exposure characteristics of the light-valve have already been pointed out,[2] and it was shown that pure sine-wave modulation by the light-valve does not always result in a pure sine-wave on the film, but rather, a complex wave with considerable second harmonic in the higher frequencies. This

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** Electrical Research Products, Inc., Los Angeles, Calif.

is the direct result of the velocity with which the film moves. Reference to Appendix *A* illustrates how the unwanted components thus introduced are eliminated in push-pull recording. A second effect of the film velocity is intermodulation between the high and low frequencies. When the modulation is sufficiently high that overload occurs, both even and odd harmonics are impressed upon the film along with other products of the overload that are of such nature as to be largely eliminated by the push-pull arrangement.

Another source of distortion may be introduced in the development and printing process. It will be recalled[3] that if the modulation of the negative is entirely confined to the straight-line portion of the negative H&D curve, and the printer point is selected to confine the modulation on the print to a similar part of the print characteristic, the true overall gamma being kept at unity, no unwanted components are introduced by the processing. However, if the gamma is permitted to depart from unity harmonics are introduced; or, the gamma being held at unity, an improper selection of negative or print density will result similarly in the introduction of harmonics, as shown by reference to Appendix *B*. The cancellation of harmonics in this case by the push-pull process is identical to that brought about by the use of the push-pull stage in amplifiers where the unwanted components are introduced by the curvature of the operating characteristic of the vacuum tubes.

Another form of unwanted component is introduced in film recording by the process of noise reduction.[4] In this case, in addition to the signal recorded upon the film, some low-frequency rectified components transmitted through the noise-reduction filter are introduced also, the effect being sometimes known as "shutter bump." The existence of this effect has restricted the application of noise-reduction principles. In push-pull recording, while the signal is recorded on the two tracks 180 degrees out of phase, the noise-reduction modulation is in phase on the two tracks. Thus, these unwanted noise-reduction components being recorded in phase, are cancelled out when the tracks are reproduced in push-pull. This makes possible a much faster-operating noise-reduction mechanism which, in turn, permits greater noise reduction. The faster type of noise reduction makes possible the use of a much smaller "margin" which, in turn, tends to reduce the "hush-hush" effect that is quite noticeable in single-track recordings of some types of recorded sounds. While push-pull recording is instrumental in largely reducing the types of

distortion listed in previous classifications, perhaps its most spectacular use has been in permitting much more effective use of noise reduction or what amounts to a much greater signal-to-noise ratio of the recording medium.

Reference has been made to the intermodulation effects due to film velocity. This intermodulation results in amplitude variations of a high frequency recorded simultaneously with a low frequency, the amplitude of the high frequency being reduced when the light-valve ribbons open under the action of the low frequency. Since in push-pull recording one half of the valve is at its maximum opening when the other half is at its minimum opening, the amplitude variations of the high frequency are opposite on the two halves of the push-pull track. Thus they tend to offset each other when the track is reproduced. Variations that might be as great as 20 per cent on a single track are reduced to only 1 $^1/_4$ per cent on the push-pull track.

Under certain conditions of processing the transmission-exposure characteristic may depart from a straight line. If the departure is at one end only, it introduces second-order harmonics which are balanced out in the reproduction of push-pull records. This form of departure also results in volume distortion and intermodulation which are, in turn, considerably reduced in push-pull. When the departure of the transmission-exposure characteristic occurs at both ends, *i. e.*, is essentially symmetrical, odd-order harmonics are introduced which can not be balanced out, and the volume distortion and intermodulation also are not reduced by push-pull. Since the "delta db." test reveals the nature of the departure of the transmission-exposure characteristic,[5] it provides a means for readily checking the value of push-pull recording in reducing this type of distortion, and for determining the amount of noise reduction that may safely be applied. The latter is usually about 14 db. in good commercial processing.

An incidental advantage of push-pull recording is its adaptability to certain forms of pre- and post-equalization recently proposed by Douglas Shearer of the Metro-Goldwyn-Mayer Studios. Since the noise-reduction action is recorded in phase on both halves of the push-pull track, any low-frequency components of this action balance out and are not reproduced as sound. Even when considerable over-emphasis of the low frequencies is given in reproduction by means of equalization the noise-reduction action or "shutter bump" is still inaudible. Therefore, by attenuating the low frequencies in recording and introducing an equivalent gain in reproducing, several

incidental improvements are obtained without any sacrifice in quality. The reduced amplitude of recorded low frequencies reduces still further the intermodulation between high and low frequencies. There is also a reduction of modulation of the ground-noise by low

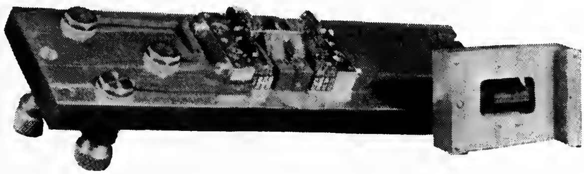

FIG. 1. Four-ribbon push-pull light-valve.

frequencies of high amplitude, since their amplitude is kept low at all times. This results in a greatly improved tonal quality or purity in this register. Since the low frequencies are reproduced through an equalizer that reëstablishes their relative levels, the high frequencies

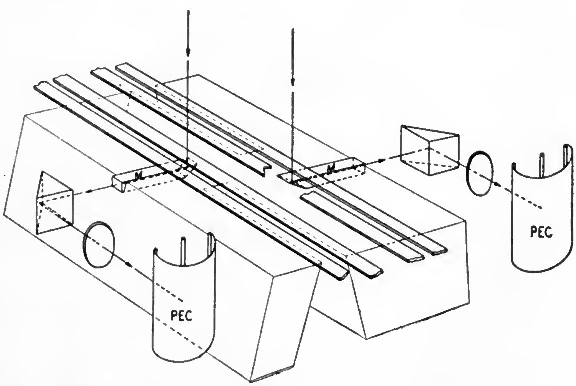

FIG. 2. Light-valve monitoring by means of quartz rods.

of the signal and of the ground-noise are reproduced through some attenuation. The result is a reduction in apparent ground-noise, with an improvement in usable volume range of at least 5 db. and a complete elimination of "hush-hush" on even the most difficult recording material.

PUSH-PULL RECORDING EQUIPMENT

(*a*) *Recording Channel.*—The microphone, recording amplifier, and mixing equipment for push-pull recording are the same as for standard recording. The noise-reduction unit is provided with a special adjustment producing a faster time of operation (of the order of 6 milliseconds). The noise-reduction current is fed to the light-valve through a potentiometer to balance the current in each half of the light-valve, thus insuring the same noise reduction on each track.

(*b*) *Push-Pull Light-Valve.*—The light-valve for push-pull recording is essentially two valves, being equipped with four ribbons instead of the customary two. A valve with similar modulating

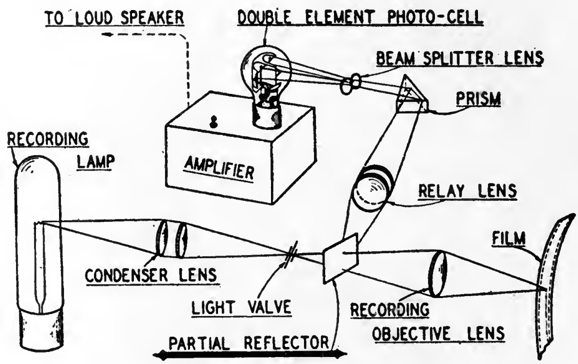

FIG. 3. Light-valve monitoring by means of partial reflector plate.

structure is described in a paper by E. C. Manderfeld.[6] A photograph of the electromagnet type of valve is shown in Fig. 1.

The normal spacing of the light-valve without bias is 1.4 mils. In order to achieve the maximum noise reduction possible, a high ratio of maximum to minimum light-valve spacing, under the control of the noise-reduction circuit, is desirable. Accordingly, the noise-reduction device has been designed to provide a reverse bias on very loud signals, thereby causing the light-valve to open to 2.0 mils. Noise-reduction settings of 14 db. are entirely satisfactory, and under very carefully controlled conditions excellent recordings have been obtained with as much as 20 db. of noise reduction. Because of the fast operation of the noise-reduction system made feasible by push-pull recording, considerably reduced margin settings are possible, as

little as 1 to 2 db. being commonly used. This results in reduced "breathing" of the ground-noise or "hush-hush."

(c) *Push-Pull Photoelectric Cell Monitoring.*—Fig. 2 shows the arrangement of the valve to provide photoelectric cell monitoring. It will also be noted that two small rods extend from each side of the valve and pass underneath each pair of ribbons. These are quartz rods which deflect a small fraction of the modulated light from each side of the valve. At the same time the mount for these rods serves

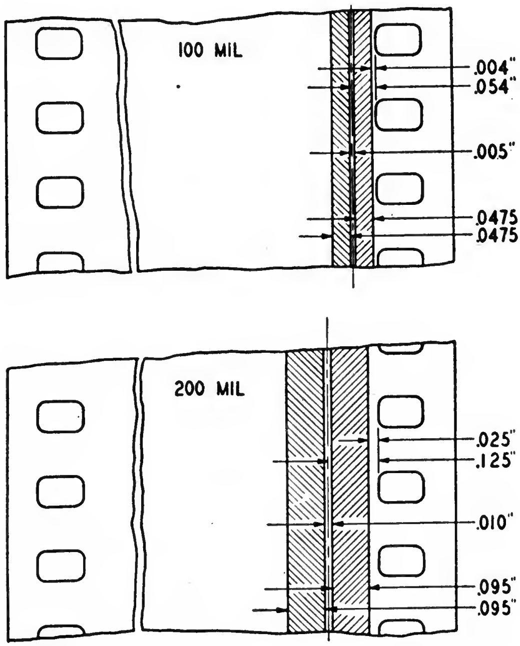

FIG. 4. Dimensions of push-pull positive sound-tracks.

to provide a septum between the two tracks. Fig. 2 shows also how the light transmitted through the rods is deflected in turn to individual photoelectric cells, the output of the cells being connected in push-pull to the monitoring amplifier. Another monitoring arrangement recently developed is shown in Fig. 3. This consists of a thin unsilvered flat glass plate mounted at 45 degrees to the recording beam, and deflecting a small portion of the entire modulated light through a suitable lens system, which in turn produces upon the

cathodes of a double-anode photoelectric cell two enlarged images of the recording slits. The monitoring system may be used for standard or push-pull recording without any change other than operating a key.

(*d*) *Optical System.*—The optical system used in push-pull recording is essentially the same as that used previously with standard recording. Because of the double light-valve, it is necessary to use a slightly longer filament in the exciting lamp. The objective lens is of the type previously described,[7] but has been specially designed to give a 4:1 reduction of the light-valve aperture at the film plane. This results in the standard track width of 100 mils, the center of the

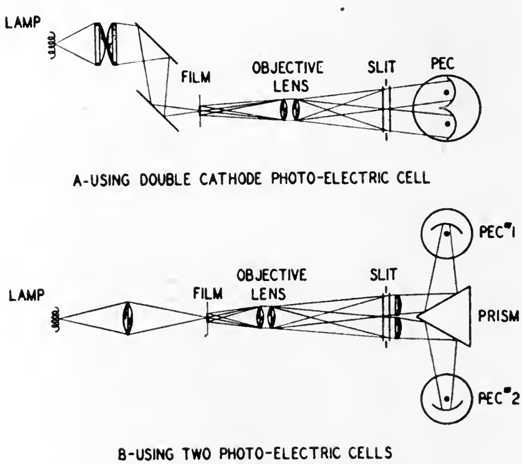

FIG. 5. Push-pull reproducer optical systems.

track being 54 mils from the inside edge of the sprocket-holes. The use of the 4:1 reduction makes it possible to use a mean light-valve spacing up to 2 mils without exceeding the $^1/_2$-mil image height which has been standard practice with 1-mil light-valves and 2:1 lens reduction. The dimensions of the track are shown in Fig. 4. For original recording from which to re-record, and where no interference between sound and picture is involved, the Metro-Goldwyn-Mayer Studios have produced push-pull sound-tracks through the original 2:1 lens. This results in a track 200 mils wide, having a signal-to-noise ratio 3 db. higher than that of the 100-mil track. The dimensions of this track are shown also in Fig. 4.

FILM PROCESSING

In general, the film-processing practices and controls that are used in processing standard variable-density track are followed for push-pull track. Because of the balancing out of certain distortion components it is possible to permit deviations from the customary practices without having to sacrifice the standard of quality. However, it is not possible to obtain all of the other benefits of push-pull re-

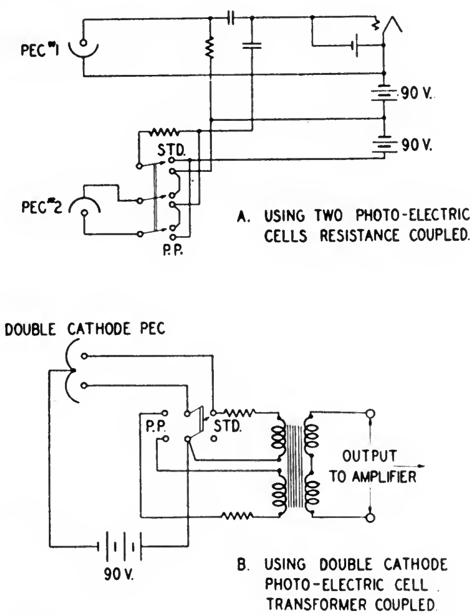

FIG. 6. Schematic diagrams of circuits for push-pull reproducing.

cording when these deviations are permitted. Thus, if no more than the usual amount of noise reduction is used, say, 8 db., there exists considerable latitude in print density and overall gamma over which a satisfactory product is obtainable. If, on the other hand, full benefit is taken of the higher noise reduction possible, then film processing is no less critical than formerly. Under this condition deviations in overall gamma result in volume distortion of the reproduced sound, and incorrect print density frequently produces both volume distortion and intermodulation of the recorded sounds, both of which may be practically non-existent at lower values of noise reduction.

PUSH-PULL REPRODUCTION

In order to reproduce two push-pull sound-tracks it is necessary to provide either two individual photocells or a special photocell having two cathode surfaces and a double anode, which amounts to placing two individual photocell units within one envelope. An optical system must be provided to collect the light from each sound-track onto the proper cathode surface. The image-scanning method of reproduction lends itself very readily to push-pull reproduction and has been used quite extensively in re-recording and in theater reproducers. Such an optical system combined with a double photocell and also with the special double anode photocell is shown in Fig. 5. In Fig. 6 is shown the method whereby either system is coupled through resistance or transformer to the amplifier. The key shown in the figure is used to switch the system from push-pull reproduction to standard single-track reproduction, this being the only change necessary to play either type of track interchangeably. Where a push-pull track width of 200 mils is used, it is necessary to provide additional means of switching from push-pull to standard, since the center-lines of the two tracks are different.

Considerable study has been necessary to determine the effects of unbalance between the two halves of the push-pull tracks. One of the factors contributing to this unbalance is weave. By proper assignment of tolerances at various steps in the overall system, it appears possible to permit a weave of approximately ± 5 mils in the reproduced sound-track without encountering appreciable degradation. In order to arrive at this permissible value of weave, studies of movement of film in recorders, printers, and projectors were made. It was found that the weave in the recorder could be held to ± 1 mil by the addition of a guide-roller above the main recording sprocket in the standard Western Electric film recorder. The printer weave that might be designated more properly as displacement of track position was found to be approximately ± 2 mils from the mean position. This may be attributed to the fact that in the regular printer the film at present is guided by one set of sprocket teeth and the width of the sprocket tooth at the base is 4 mils less than the sprocket-hole dimension. It was not possible to study the amount of weave that may be present in all types of projectors, but it was found that in certain well maintained machines the weave introduced was of the order of ± 2 mils. Since in all probability these individual weaves will rarely be all in the same direction at the same

time, the resultant weave will seldom amount to the ±5-mil tolerance permitted by the scanning system.

(*a*) *Track Balance.*—The improvement to be obtained from push-pull recording by the cancellation of distortion may be realized fully only when the outputs from the individual photocells in the reproducer are equal, *i. e.*, in balance. Differences in sensitivity of the translating devices or in the modulation of the two tracks will necessarily mean that instead of complete cancellation of unwanted components, residuals of these components will be present to some extent. In considering the various elements that contribute to an overall balance of the two push-pull tracks, the following factors may be listed:

(*1*) Uniformity of illumination of the exposing beam in recording.
(*2*) Equal sensitivity of the two component valves.
(*3*) Uniformity of illumination of the printer light.
(*4*) Uniformity of illumination of the reproducer scanning beam.
(*5*) Equality of sensitivity of cells and associated coupling circuits in reproduction.

Contrary to the general impression, the balance of the tracks is not affected by changes that may occur in valve spacing so long as the valve sensitivity remains unchanged. This assumes that such change of spacing does not cause one-half of the track to assume a non-linearity of characteristic not already present. This is best understood by reference to Appendix *C*.

With regard to the first three items mentioned above, the illumination of the exposing beam can be kept within close limits by correct adjustment of the exciting lamp with respect to the light-valve apertures. It has been found that the coiled filament type of lamp generally used is very uniform in illumination across the useful length of the filament. The sensitivity of the two valves can easily be adjusted within $^1/_2$ db., and will continue to remain balanced to this extent unless severely abused in the recording process. A study made of several printers indicated that the variation of illumination across the printer aperture in a commercial printer probably introduces the greatest possibility of unbalance between the tracks. The net unbalance in output resulting from variations in negative and positive density, from inequality in light-valve sensitivity, and from variation in printer illumination, has been found to amount to a maximum of about 2.5 db.

In reproducing circuits involving the use of two individual photoelectric cells, these may be selected having a sensitivity unbalance of not more than 1 db., and it has been found possible to produce a double photocell having an inherent unbalance of the same order of magnitude. Thus a maximum of about 3.5 db. is the most that may be expected in the unbalance of two push-pull tracks when due precautions have been taken to see that the various elements are lined up with the degree of accuracy found feasible under studio conditions.

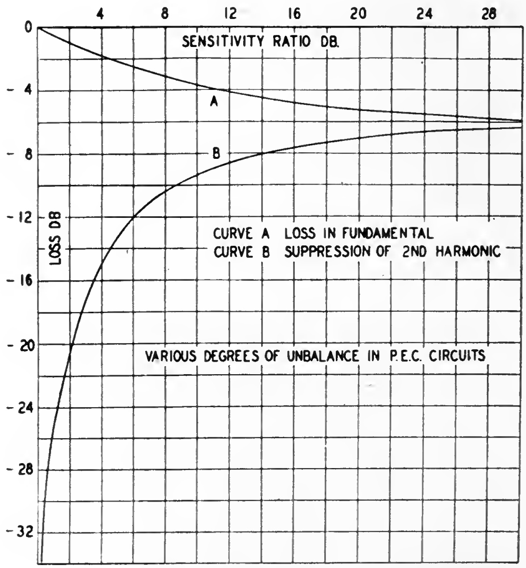

FIG. 7. Effect of unbalance between sides in push-pull system.

In order to appreciate what the effect of unbalance between the two tracks means to the suppression of unwanted components, the mathematical analysis shown in Appendix *D* has been made, the graphical results of which are shown in Fig. 7. The curves show that a difference in sensitivity of 3 db. results in the reduction of the wanted components by about 1.5 db., but suppresses the second-order distortion components by about 17 db.; this amount of suppression to be added, of course, to the amount by which they are already attenuated in the film modulation. It has been shown[1] that in single-track light-valve recording in which the image height is 0.5 mil, the second harmonic

at 4000 cycles is 19.5 db. below the fundamental. Additional suppression of only 15.5 db. would reduce this to a total of 35 db., corresponding to 1.8 per cent of second harmonic. Since the third harmonic has been shown to be negligible in the recording range, we thus see that the push-pull recording essentially eliminates the unwanted components that are present in standard light-valve recording. It will be recalled that in this process a maximum spacing of 2 mils is permitted, but when this is associated with the 4:1 lens reduction, the image height is still retained at the 0.5-mil value which has been more or less the practice in standard recording. The next principal source of harmonics is introduced in the film processing, and experience has shown that if the overall gamma is not permitted to vary more than 20 per cent from the mean value of unity, the second harmonic will not exceed more than 5.0 per cent of the fundamental. If we add this to the ribbon-velocity components and assume the 15.5-db. suppression, we arrive at a total suppression at 4000 cycles of 31.5 db.

EXTERNAL BALANCING OF PHOTOCELL OUTPUT

In the preceding discussion on the degree of balance to be expected in push-pull recording, it has been assumed that no special means was to be used to achieve better balance than could be accomplished by carefully lining up the equipment and taking all necessary precautions in recording and reproducing to see that no unnecessary unbalance is introduced. However, it is quite possible to balance the output of the two photoelectric cells either by reducing the light-flux of the scanning beam on the cell showing the greatest output, or by altering the potential of the cell anodes in such manner as to balance their outputs more effectively. With either of these methods it has been found possible to suppress the unwanted components as much as 30 db., which is considerably more than is necessary.

TRACK ALIGNMENT

A cause of unbalance that has not been discussed hitherto is misalignment of the images on the two tracks. It will be recalled that the two apertures in the light-valve pole-piece are separated by a considerable distance and that the two recording beams passing through these apertures are brought into line by the use of refractor plates. An analysis has been made to determine what the effect of alignment is upon the passage of the wanted and the suppression of the unwanted components. The mathematical analysis is indicated

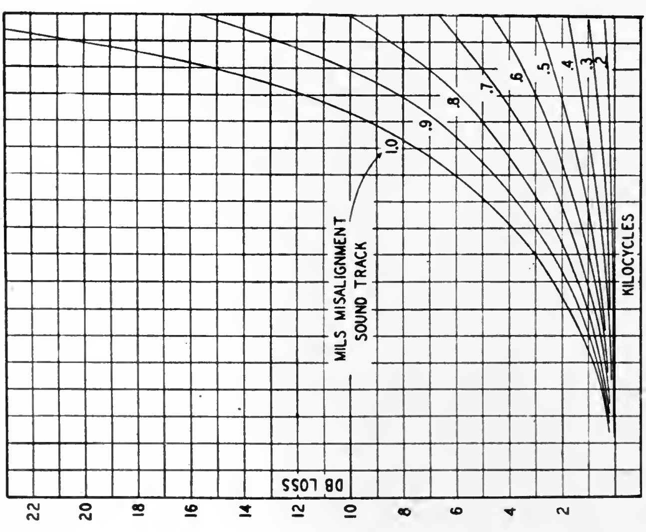

FIG. 8. Effect of image misalignment in push-pull system; loss of frequency response.

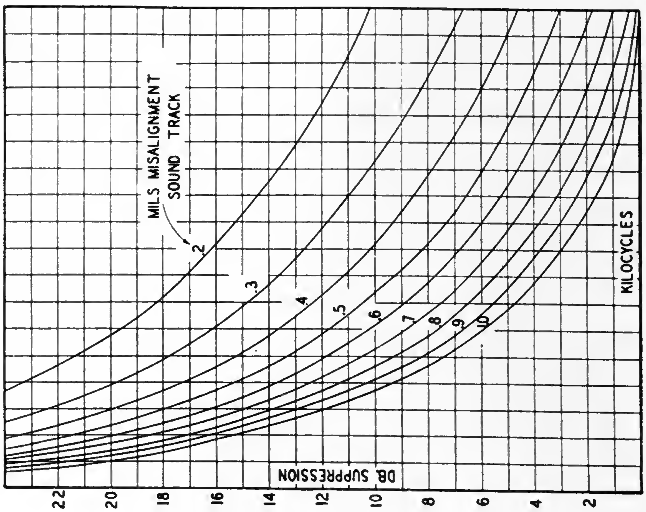

FIG. 9. Effect of image misalignment in push-pull system: suppression of second-order effects.

in Appendix *E*, while in Fig. 8 is shown the loss of wanted signal for frequencies up to 9000 cycles, and in Fig. 9 is shown the degree of suppression of the unwanted components for misalignment values varying from 0.2 mil to 1 mil. It will be noted that the effects are negligible for misalignment at the film of less than 0.2 mil. Due to the use of the 4:1 reducing lens, misalignment of that amount corresponds to effective misalignment of 0.8 mil at the light-valve. In practice it has been found quite feasible to make alignment adjustments within a very small fraction of this requirement.

CONCLUSION

It has been shown that the principal distortions in light-valve recording, such as result from ribbon velocity effect, light-valve

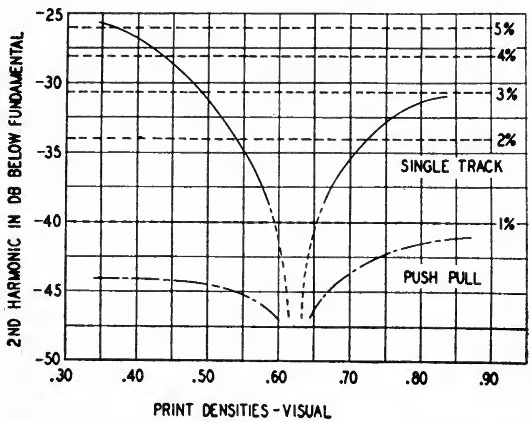

FIG. 10. Comparison of second-harmonic distortion: single track *vs.* push-pull track.

overload, and errors in film processing, have been materially reduced by the push-pull method. In addition, the low-frequency noise-reduction components and certain other extraneous components of accidental overload of the light-valve in regular recording are eliminated in the push-pull process, since they are recorded in phase upon the two component tracks. This makes possible the use of increased noise reduction, up to 14 db. being regarded as commercially practicable. In reproduction no trouble has been experienced from normal weaving of the sound-tracks. It has been shown that the degree of unbalance that may be introduced in the output of the two tracks arising from errors of operation and other discrepancies introduced

in the overall process is sufficient to suppress the unwanted components more than the 15 db. believed to be sufficient. Further improvement has been made possible by balancing devices in the reproducing mechanism, where the utmost is required for re-recording purposes. Additional advantages can be obtained by combining pre- and post-equalization with push-pull, thereby achieving greater signal-to-noise ratio, better tonal quality of the low frequencies, and complete elimination of "hush-hush."

In the practical operation of push-pull systems in the studios, the two qualities that appeal most to the recording engineer are the additional noise reduction made possible by the method and the elimination of the harsh quality that has hitherto been characteristic of light-valve overload. The method also permits considerable reduction in the modulation of the light-valve for low input sounds which in the past would have been masked by the background noise. This permits more natural recording of the volume range without raising the low signal or depressing the high signals; in fact, for the great bulk of recorded material, such as dialog, little mixing is necessary with the push-pull method outlined here.

At the present time the use of push-pull recording is limited to original recording, since comparatively few theaters are as yet equipped to play push-pull track. However, a definite gain is obtained in recording from this type of track to the standard single track, compared to re-recording from standard to standard track.

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APPENDIX A

The exposure impressed upon moving film by a two-ribbon valve is given by the equation:

$$e_1 = 2a + \frac{4v}{w}\left[j_1\left(\frac{bw}{v}\right)\cos\frac{aw}{v}\sin wt + \tfrac{1}{2}j_2\left(\frac{2bw}{v}\right)\sin\frac{2aw}{v}\cos 2\,wt + {}^1/_3 j_3\text{-}\left(\frac{3bw}{v}\right)\cos\frac{3aw}{v}\sin 3\,wt + \ldots\right] \qquad (1)$$

This may be written as:

$$e_1 = A + B\sin wt + C\cos 2\,wt + D\sin 3\,wt + \ldots \qquad (2)$$

where A, B, C, D correspond to the coefficients of the time function above. If eq. *2* represents the wave-form on one track, the wave-form on the track 180 degrees out of phase is

$$e_2 = A + B\sin(wt - 180) + C\cos 2(wt - 180) + D\sin 3(wt - 180) \qquad (3)$$

On the print, for correct development, the transmission wave-forms will correspond to the above. Hence we may express the resultant wave-form, when the two tracks are correctly reproduced in push-pull, as the difference of the above. Thus the output

$$e = e_1 - e_2 = 2\,B\sin wt + 2\,D\sin 3\,wt + \ldots \qquad (4)$$

all even harmonics cancelling out.

APPENDIX B

The relation between print transmission and negative exposure for film processing where the gamma is other than unity is:

$$T_1 = K(1 + b\sin wt)^\gamma \qquad (5)$$

Where T = print transmission.
K = a constant.
b = film modulation.
γ = overall gamma of developing process.

Thus

$$T_1 = k\left[1 + \gamma b\sin wt + \frac{\gamma(\gamma-1)b^2}{2}\sin^2 wt + \frac{\gamma(\gamma-1)(\gamma-2)b^3}{6}\sin^3 wt + \ldots\right] \qquad (6)$$

This reduces to

$$T_1 = K\left[\left\{1 + \frac{\gamma(\gamma-1)b^2}{4}\ldots\right\} + \left\{\gamma + \frac{\gamma(\gamma-1)(\gamma-2)b^2}{8}\right\}b\sin wt - \frac{\gamma(\gamma-1)B^2}{4}\cos 2\,wt - \gamma\frac{(\gamma-1)(\gamma-2)}{24}b^3\sin 3\,wt\right] \qquad (7)$$

which may be written as

$$T_1 = K[a + b \sin wt - c \cos 2\,wt - d \sin 3\,wt]$$

As in appendix A_1 a similar wave-form 180 degrees out of phase on the second push-pull track will result in complete cancellation of the second-harmonic term. An illustration of the measured cancellation of second harmonics over a wide range of prints density is shown in Fig. 10.

APPENDIX C

The sample equation of exposure for the light-valve is:

$$e_1 = a + c \sin wt$$

where a = normal spacing of ribbons and c = amplitude of ribbon movement.

Assume that the second valve in a four-ribbon valve is spaced ma units, and that its sensitivity is the same as first valve. Then the exposure through valve No. 2 is $e_2 = ma + c \sin wt$.

Now on the print the transmission of track No. 1 is $T_1 = k(a + c \sin wt)$ and that of track No. 2 is $T_2 = k(ma + c \sin wt)$. The voltage developed by each track is thus $kc \sin wt$ and is independent of m. This assumes that m is of such value that the resultant exposure in valve No. 2 does not bring out a photographic unbalance in the modulation of the two tracks.

APPENDIX D

Assuming that equal sinusoidal signals are recorded on both tracks, the voltage impressed upon the grid of the first amplifier tube derived from track No. 1 is:

$$E_1 = b \sin wt + c \sin 2\,wt$$

Similarly for track No. 2

$$E_2 = nb \sin wt - nc \sin 2\,w$$

where n is the sensitivity ratio of the translating device. The resultant voltage is:

$$E = b(1 + n) \sin wt + c\,(1 - n) \sin 2\,wt$$

The output of a push-pull reproducing device thus unbalanced relatively to that of a balanced system is:

$$db. = 20 \log \frac{1 + n}{2}$$

The corresponding function for the second harmonic represents suppression of that component, and is expressed as:

$$db. = 20 \log \frac{1 - n}{2}$$

The output of second harmonic relative to the fundamental for any degree of unbalance of the translating devices is:

$$db. = 20 \log \frac{1 - n}{1 + n} + 20 \log \frac{c}{b}$$

APPENDIX E

Track Misalignment.—Assume k = linear displacement on the film between corresponding points of the signals, and v the speed of the film in reproduction. The voltages impressed on the grid from tracks No. 1 and No. 2 are, respectively,

$$E_1 = a \sin wt$$

$$E_2 = a \sin\left(wt - \frac{wk}{v}\right)$$

$$= a \sin wt \cos\frac{wk}{v} - a \cos wt \sin\frac{wk}{v}$$

or

$$E = E_1 + E_2 = a\left(1 + \cos\frac{wk}{v}\right)\sin wt - a \sin\frac{wk}{v}\cos wt$$

This reduces to

$$E = 2a \cos\frac{\phi}{2}\sin(wt - \phi)$$

where

$$\phi = \tan^{-1} a\left(\frac{\sin\frac{wk}{v}}{1 + \cos\frac{wk}{v}}\right)$$

The loss of wanted signal is

$$db. = -20 \log\frac{2a}{2a}\cos\phi/2$$

$$= -20 \log \cos\phi/2$$

The voltages of the unwanted signal from each track are similar to the above. Their resultant, however, is the difference rather than the sum of the individual voltages.

The amplitude of the unwanted signal becomes $E = 2a \sin\phi/2$. The suppression is $db. = -20 \log \sin\phi/2$.

DISCUSSION

MR. DAY: Is this suppression of noise or "hush-hush" considered a novelty? I demonstrated this principle in 1930 and 1931.

MR. FRAYNE: Post-equalization is well known. It has been used commercially in hill-and-dale recording for about seven or eight years and experimentally for a considerably longer period. It is possible to find many things that have been done in years gone by that have not been followed up, or did not originally work well because of some difficulties at the time.

The form of equalization used here is not that used in the hill-and-dale method. This particular type was developed by Douglas Shearer, of M. G. M., and is a peculiar form of equalization which reduces not only the film noise but also the "breathing" or "hush-hush" effects.

MR. DAY: I believe my organization put out the first sound-on-film 16-mm. projector, and, perhaps foolishly, we used the light from the projection lamp for exciting the photoelectric cell. Naturally we had a great deal of noise, so we used the same arrangement that you showed today, with two photoelectric cells bucking each other. Into the one cell we put a beam of light that had only noise in it, and into the other a beam modulated by both noise and sound. We had very satisfactory sound by that arrangement, and found that neutralizing by two cells worked very well, but we had quite a little difficulty in magnetic elimination through transformer coils.

MR. KELLOGG: I did not quite understand why the push-pull system makes it possible to get better results out of pre-equalization than you could anyhow. Am I correct in assuming that the pre-equalization is essentially what is shown in Mr. Friedl's paper? If so, why was that particular form chosen?

MR. FRAYNE: The reason why push-pull is desirable is that the noise-reduction frequencies, which I spoke of as unwanted components, being in phase on both sides of the track, are relatively low-frequency effects. When you raise the low frequencies 12 db. to bring up the low end in the post-equalization characteristic, you bring up the unwanted components by 12 db.; to a point where, in some kinds of recording, especially of pianos or drums, they would be above the desirable level. The cancellation that the push-pull system offers is very desirable in getting rid of those frequencies.

The particular curve was arrived at by considering the energy distribution in both speech and music, film noise, and ear sensitivity, and interrelating these in such a manner as to obtain the best possible signal-to-noise ratio. This results in practically eliminating the "hush-hush" and other effects resulting from high-amplitude low frequencies.

MR. KELLOGG: In other words, the equalization is more or less complementary to your observed or experienced spectral distribution.

MR. FRAYNE: More or less.

REPORT OF THE STANDARDS COMMITTEE*

The recent publication[1] of the "Revision of SMPE Standards Proposed for Adoption by the Society" summarizes the activities of the Standards Committee for the past two or three years. These drawings have all received initial approval and final approval by the Committee and are referred to the Board of Governors of the Society for approval.

Unfavorable comments have been received in regard to the sound-track dimensions both for 35-mm. and 16-mm. film. In the opinion of the Chairman of the Committee these comments justify withholding adoption of these two standards until further study is undertaken.

There have been very few comments on any other drawings and it is recommended that all other drawings be adopted by the Society.**

The uncompleted items at present under consideration are as follows:

(*1*) A study of the best dimensions for standard cores for cine film, being made by P. H. Arnold.

(*2*) Further consideration of all the dimensions for 35-mm. and 16-mm. sound-tracks.

(*3*) Drawings for sprockets for 16-mm. sound-film. These may depend, to a certain extent, upon possible modifications of the sound-track dimensions.

(*4*) Revision of the standard release print to correspond with the revisions made by the Academy.

(*5*) Review and possible revision of the glossary of technical terms.

(*6*) Carrying out of actual tests of the new sprocket perforation of 35-mm. film, which, it is hoped, will displace the old Bell & Howell perforation.

Two punches and dies have been constructed in accordance with the specifications originally outlined by Howell and Dubray,[2] and another punch has been constructed by the Agfa Ansco Corporation using the same radius at the corner as the present SMPE perforation. Tests have been made, and further tests are under way, comparing these two types of perforation both for breakdown in the projection ma-

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 22, 1938.

** Subsequently to the preparation of this report, action on the proposed revision of the standards was taken by the Board of Governors (April 24, 1938), all the proposals being validated as SMPE Standards with the exception of *DS35-7-1* and *DSs16-7-1*, relating to 35-mm. and 16-mm. sound-tracks.

chine and for steadiness in various types of cameras. Preliminary tests give some indication that the Howell and Dubray perforation is not quite as good as the SMPE perforation for durability in projection, although it is considerably better than the Bell & Howell perforation. Tests also indicate that in some cameras the positioning of the new perforation is exactly as good as with the Bell & Howell perforation, but that in other cameras it is not quite as good. These two points will have to be established definitely before a decision can be made.

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THE INFLUENCE OF pH ON WASHING FILMS AFTER PROCESSING*

S. E. SHEPPARD AND R. C. HOUCK**

Summary.—*Advantages stated to be obtained by adjusting fixing baths and wash-water to the isoelectric point of gelatin have been claimed. The advantages are said to be shorter washing time, less swelling and retention of water, with consequent improvement in the jelly strength of the wet emulsion, and reduced drying time. In the present investigation the conditions as to pH of the solutions, and wash-water, rate of flow of water, residual thiosulfate, etc., were controlled accurately. The results indicate that with a regular acid fixing and hardening bath (F-25) there is no advantage, but rather a disadvantage in washing at the isoelectric point (ca. pH 4.9) rather than at pH 7 to 8, since the time required to remove hypo to the same degree is increased, nor is less water retained. In a non-hardening acid fixing bath, there was little difference in washing time, but some gain in drying time for the isoelectric wash because of reduced water absorption.*

The principal object of washing processed film is to remove as completely as possible the salts of the fixing bath, and particularly thiosulfate, otherwise "hypo." The retention of relatively very small amounts of hypo makes the image liable to discoloration and deterioration.[1] The investigations of Hickman and Spencer[2] have demonstrated that with efficient mechanical conditions hypo can be washed out of a photographic (plate) layer of normal thickness in quite a short time; they estimated the permissible residue in terms of the lowest density it was desired to conserve (against sulfiding or sulfating)—then assuming a safety factor of 10, suggested 0.00016 gram per sq. decimeter, or about 0.008 mg. per sq. inch. However, in their investigations no particular attention was paid to *p*H conditions as effecting the efficiency of washing.

Recently this factor has been considered by D. K. Allison,[3] who claims that washing should be done with water adjusted to the isoelectric point of the gelatin used in the emulsion. He states that

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 21, 1938. Communication No. *666* from the Kodak Research Laboratories.

** Eastman Kodak Company, Rochester, N. Y.

washing is accomplished in shorter time with consequent smaller water absorption by the gelatin, hence also less water consumption and shorter drying time. In his U. S. Patent 1,954,512 (1934) he proposes to have the *p*H of both fixing bath and wash water adjusted to the same value. In discussion of this proposal[3] it is stated that "At *p*H values other than the narrow range of maximum efficiency, the salts such as hypo and alum are *chemically combined with the gelatin and can not be entirely* removed." (Italics in original.) This statement is not precisely correct. In general, gelatin as an amphoteric electrolyte does not combine with salts, but with ions; at *p*H values lower than the isoelectric point, the gelatin becomes more negatively charged and has a greater attraction (electrostatic) for anions, while the converse is the case for *p*H values greater than the isoelectric point, when the attraction for anions diminishes, but increases for cations. These facts are currently employed in processes of de-ashing gelatin,[4] the removal of anions ($\overset{=}{S}O_4$, $\overset{\equiv}{P}O_4$, $\overline{C}l$, *etc.*) being effected by washing with alkaline water—*p*H 8–10, then the combined cations are removed by washing in weak acid (dilute acetic, *p*H *ca.* 4), finally with distilled water, *p*H 5.5, which removes excess acetic until the *p*H approaches the isoelectric point, *ca.* *p*H 5. The isoelectric point of gelatins used in photographic emulsions may vary from about *p*H 4.7 to *p*H 5.2. As the *p*H of wash water is lowered from about 7.5 or 8 (service water) to 5 or lower, the attraction for $\overset{=}{S}_2O_3$ (thiosulfate) and $S\overset{=}{O}_3$ (sulfite) ions is increased, and their removal is not facilitated, but hindered. In the paper and patent of D. K. Allison, no criterion is given of completeness of washing in respect of removal of hypo, nor is the washing procedure described in any precise fashion. In view of the facts and claims cited it seems desirable to study the effect of *p*H upon washing, using a mechanically reproducible procedure, and an efficient test for removal of hypo.

EXPERIMENTAL

All the experiments were made at 18°C (64.4°F). The emulsion used was Eastman motion picture positive. The solutions used during processing are outlined below:

(*1*) The developer was *D-16* without the developing agent. The developing agent was omitted to facilitate the test used to determine satisfactory washing. This will be described separately. The time of development in all cases was 5 minutes.

(*2*) A rinse water of 15 seconds was inserted between the developer and fixing bath. This rinse water was the same as the final wash water.

(*3*) Various fixing baths were used. The first tests were made with *F-25,* an acid hardening fixing bath recommended for use with Eastman motion picture positive film. The *p*H was varied from 4.1 as received to *p*H 4.8, depending upon the test.

Other experiments were made with non-hardening fixing baths. The *p*H was varied in these cases from *p*H 4.1 to 4.8. The time of fixation in all cases was 5 minutes. The results with hardening and non-hardening fixing baths will be described separately.

(*4*) The wash water used was tap water with a *p*H, as taken,

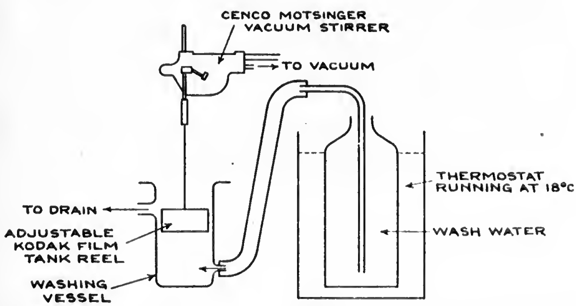

FIG. 1. Diagram of washing apparatus.

varying from 7.8 to 8.0. In part of the experiments the *p*H of the tap water was reduced to *p*H 4.8 by addition of acetic acid.

The rate of flow of water through the washing apparatus was 275 cc. of water per minute. This was checked during each experiment.

The film to be washed was wound onto a reel from an adjustable Kodak film tank. This reel gives a continuous $^1/_8$-inch separation of the film throughout its entire length of 5 feet. The reel fits nicely into 1500-cc. beakers, which were used in the processing. After developing, rinsing, and fixing, the reel was connected to the shaft of a Cenco Motsinger vacuum stirrer and lowered into the washing vessel. This stirrer is operated either by water suction or vacuum pump, and gives an up-and-down movement of 69 times per minute. The wash water was siphoned from the container in the thermostat at the rate of 275 cc. per minute. The washing set-up is shown diagrammatically by Fig. 1.

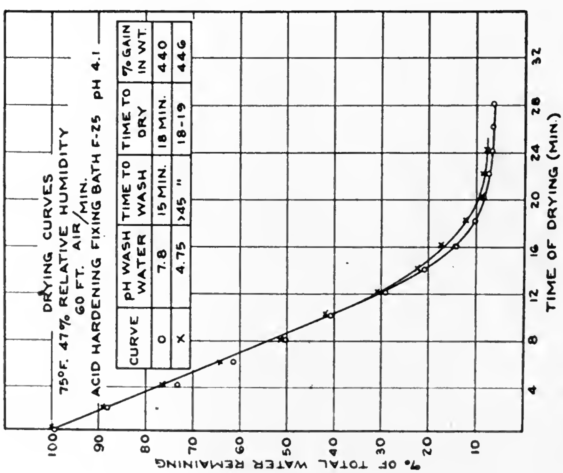

FIG. 2. Typical results with acid fixing bath *F-25* at *p*H 4.1.

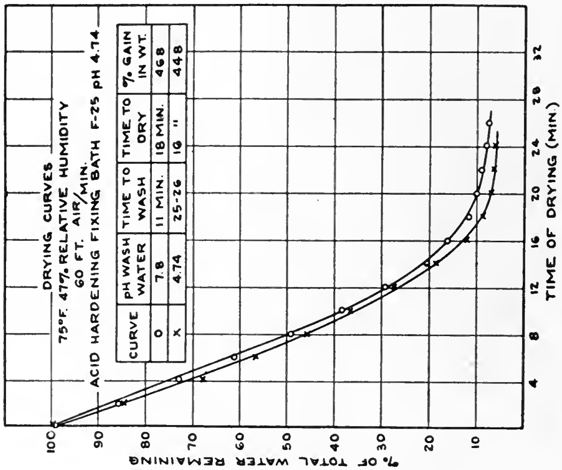

FIG. 3. Results with fixing bath *p*H increased to 4.74.

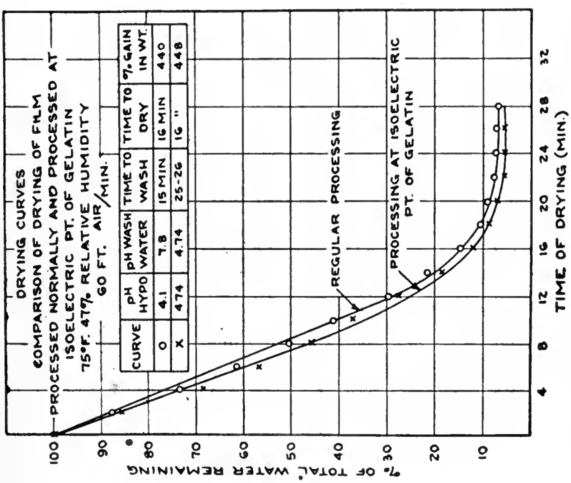

FIG. 4. Comparison of regular processing and processing at isoelectric point of gelatin.

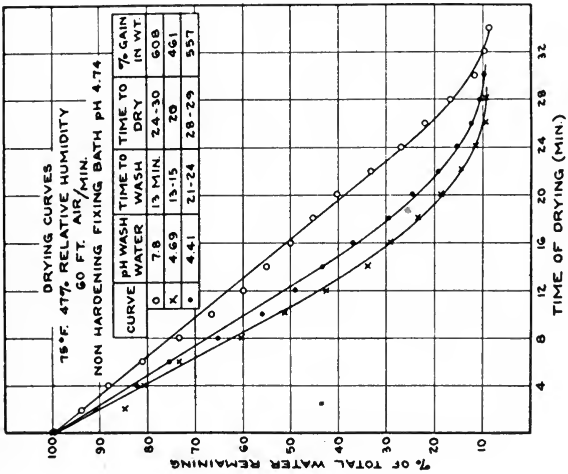

FIG. 5. Results with non-hardening fixing bath.

Washing was continued until a negative azide test on the fixed emulsion itself was obtained. The azide test used was that described by Jelley and Clark.[5] The solutions were made as described and recommended by them. The test was made on the gelatin surface instead of the wash water. A definite amount of the test solution 0.05 c. c. was placed upon the gelatin surface after removing ex-wash water by blotting. This solution was spread over a square-inch of surface. If the blue color persisted after one minute, the film was considered washed. The time in minutes to reach this point was taken as the washing time, tests being made every two minutes. The test was facilitated by using *D-16* without developing agent, the change from blue to colorless being easy to see.

Percentage gains in weight, drying rates, and drying times were determined on the washed film. The drying rate and drying time were determined by removing the excess water from the washed film by blotting off with filter paper, then placing this film in a drying atmosphere. The drying was done at 75°F with air at 47 per cent relative humidity moving over the film at the rate of 60 feet per minute. Weighings were made every two minutes until approximately constant weight was obtained. The time for the emulsion to be dry to the touch was also determined. This is given as the drying time in all the tables of data. Actually the emulsion continued to lose weight for several minutes after the "dry-to-the-touch" point was obtained. The emulsion then was dried further over phosphorous pentoxide. The weight of the sample was determined by washing off the dried gelatin and weighing the base. From the data obtained, the percentage gain in weight was calculated.

The results obtained with hardening and non-hardening fixing baths will be described separately.

Acid Hardening Fixing Baths.—Typical results obtained using the acid hardening fixing bath, *F-25*, at *p*H 4.1 are given in Table I. The drying curves are given in Fig. 2.

TABLE I

Effect of pH of Wash Water on the Washing and Drying of Motion Picture Film Processed with Acid Hardening Fixing Bath at pH 4.1

Fixing Bath	*p*H Fixing Bath	Wash Water	*p*H Wash Water	Time to Wash	Time to "Dry to Touch"	% Gain in Weight
F-25	4.1	Tap water	7.8	13–15 min.	18 min.	440
F-25	4.1	Tap water + AcOH	4.75	>45 min.	18–19 min.	446

As can be seen from the data and curves, lowering the *p*H of the wash water from *p*H 7.8 to 4.75 has not resulted in a shorter washing time but, on the contrary, has increased the washing time considerably. The drying times are about the same, a fact that one would expect since the percentage gains in weight are practically the same. Agreement in the drying times is further checked by the drying curves. These coincide almost exactly.

TABLE II

Effect of pH of Wash Water on the Washing and Drying of Motion Picture Film Processed with Acid Hardening Fixing Bath at pH 4.74

Fixing Bath	*p*H Fixing Bath	Wash Water	*p*H Wash Water	Time to Wash	Time to "Dry to Touch"	% Gain in Weight
F-25	4.74	Tap water	7.8	10–11 min.	18 min.	458
F-25	4.74	Tap water + AcOH	4.74	25–26 min.	16 min.	448

Data obtained similarly, but with the *p*H of the fixing bath increased to *p*H 4.74, are given in Table II and Fig. 3. Again, lowering the *p*H of the wash water from *p*H 7.8 to 4.74 has not decreased but has increased the washing time.

Comparing the case claimed by Allison as giving the greatest gain, that in which the fixing bath and the wash water are at the *p*H of the isoelectric point of the gelatin, with the one in which the fixing bath is at *p*H 4.1 and the wash water at *p*H 7.8, it is seen from data in Table III that again the time to wash is increased at *p*H 4.74, with an insignificant gain in drying This is shown in Fig. 4.

TABLE III

Comparison of Film Processed Normally and Film Processed with All Solutions except Developer at pH of Isoelectric Point of Gelatin

Type of Process	Fixing Bath	*p*H Fixing Bath	Wash Water	*p*H Wash Water	Time to Wash	Time to "Dry to Touch"	% Gain in Weight
Normal	*F-25*	4.1	Tap water	7.8	13–15 min.	18 min.	440
"Iso"	*F-25*	4.74	Tap water + AcOH	4.74	25–26 min.	16 min.	448

In the case of an acid hardening and fixing bath, when the criterion of hypo removal was the azide test, isoelectric washing increased the time required for washing, and showed no appreciable gain in drying. The azide test, in the presence of gelatin, detects definitely between 0.05 to 0.01 mg. per sq. inch, which tends to the same order as the safety factor suggested by Hickman and Spencer.

Non-Hardening Fixing Baths.—Similar studies were made with non-hardening fixing baths, the fixing bath used being *F-25* without hardening agent. In this case the *p*H of the fixing bath was raised to *p*H 4.72 in all the experiments.

Typical results obtained are given in Table IV and Fig. 5.

TABLE IV

Effect of pH of Wash Water on the Washing and Drying of Motion Picture Film Processed with Non-Hardening Fixing Bath F-22 without Alum

*p*H Fixing Bath	Wash Water	*p*H Wash Water	Time to Wash	Time to Dry	% Gain in Weight
4.72	Tap water	7.8	13 min.	29–30 min.	608
4.72	Tap water + AcOH	4.69	13–15 min.	20–21 min.	461
4.72	Same	4.59	17–19 min.	23 min.	510
4.72	Same	4.41	21–24 min.	28–29 min.	557

As seen from the data in the table, there is no shortening of the washing time on lowering the *p*H of the wash water from 7.8 to *p*H 4.69. Less water is taken up by the gelatin, and this accounts for the shorter and faster drying. This decreased drying time checks the results obtained by Allison but, on the other hand, the time to wash is not materially reduced. If the *p*H is decreased to *p*H 4.41, the time to wash, per cent gain in weight, and drying time increase.

It is concluded from the results obtained that washing of an emulsion that has been processed with non-hardening fixing baths is improved by the use of wash water at the isoelectric point of gelatin only in that the amount of wash water taken up is decreased. This results in a decreased drying time.

Our thanks are due to Mr. C. Dittmar, who carried through a large number of the experiments described in this paper.

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PROBLEMS INVOLVED IN FULL-COLOR REPRODUCTION OF GROWING CHICK EMBRYO*

E. S. PHILLIPS**

Summary.—*Attempts to record on 16-mm. color-film the structural changes taking place during the 21-day incubation period of the hen's egg present problems varying with each day's growth. Because the authors were working with living subjects that required strict adherence to narrow tolerances in order to maintain normal embryological development and even life itself, it was necessary to adapt photography to the problem—not the reverse, as is often possible.*

Development of the embryo is shown in three different ways, i. e., by transmitted light, with shell entire; removal of part of the shell and subsequent photography by reflected light; removing the entire shell and placing the embryo in a watch crystal, thus showing all parts in relative sizes.

In all three methods, temperature, humidity, and light control constituted the major problems. Special equipment devised to meet the requirements of both normal incubation and photography had to be built, and the use of mineral oil to obtain a transparent plane surface over the opaque, irregular, inner membrane of the egg's air-cell was evolved.

Color motion pictures have provided a distinct contribution in reproducing accurately the structural changes occurring during the incubation period.

The recent introduction of easily manipulated color-film has now made possible the recording of biological phenomena that hitherto have been unsuccessfully reproduced on black-and-white film. This results because of the distinct limitations of black-and-white film in recording brightness differences that become immediately obvious when portrayed in color.

A biological occurrence of this kind has recently been solved by Professor Alexis Romanoff, of the Poultry Department of Cornell University, and the author. The problem was to show the process of development that takes place during the 21-day incubation period of a hen's egg. Inasmuch as the authors were dealing with problems so close to the creation of life, namely, the formation of a living animal as it progresses through the delicate changes preceding hatching, and

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** Cornell University, Ithaca, N. Y.

final independence as an individual, photographic methods had to be limited to the narrow tolerances vital to maintaining normal development and even life itself.

The Motion Picture.—Very few persons have witnessed the miraculous transformations that take place within the protective shell of an egg as a new living creature develops. In the short period of three weeks a seemingly inert object assumes definite form, emerges from its confining walls, and independent life begins. To portray this miracle adequately, the authors and Mr. Meade Summers of the Ralston Purina Company, sponsors of the project, determined to show development in three ways. The first series of pictures depicts growth as seen through the shell wall by means of transmitted light. The second series was made by cutting a hole about one inch in diameter at the blunt end of the egg. With the proper lighting alignment it was possible to see clearly within the egg itself. In the third series the entire contents of the shell were emptied into a large watch-crystal. As a grand finale an egg actually hatches before the camera lens.

Problems Involved.—The problems involved in filming this sequence of events were the same as those in controlling normal incubation conditions. The temperature of the egg had to be maintained at $99^1/_2°$ F. Humidity, although not so critical as temperature control, nevertheless had to be kept as near the optimum value as possible. Since normal development was shown three different ways, these conditions varied slightly in each case.

Photographic Equipment.—The photographic equipment constituded a 16-mm. Eastman Special camera with a 1-inch $f/1.9$ lens, a 3-inch $f/4.5$ lens, and a 4-inch $f/2.7$ lens. The time-lapse mechanism made expressly for the Eastman Special was used for all pictures taken by transmitted light.

Pictures by Transmitted Light.—Commercial hatcherymen normally view incubating eggs by candling; that is, by placing the unbroken egg before a light-source and viewing the contents by transmitted light. To duplicate this practice a special incubator box and lamp-housing were designed, shown in Fig. 1. Light from a No. 4 photoflood lamp passed through a water-cell which removed heat radiating from the bulb. Slightly above the water-cell a condensing lens focused the light upon the egg. The egg was supported by an opaque, velvet-covered mat with a hole the exact shape but slightly smaller than the minimum egg size. The entire mat was held in a glass-covered incuba-

tor box. A velvet-lined tube extended from the plate-glass covering of the incubator box to the camera lens, to protect the egg from any possible extraneous light. Heat within the box was supplied by ordinary resistance wire, controlled by a thermostat to within 0.2°F. To guard against short periods of overheating, a water cooling-coil was installed. Conduction of heat from the lamp-housing was reduced by forced ventilation. The same incubator box was used with

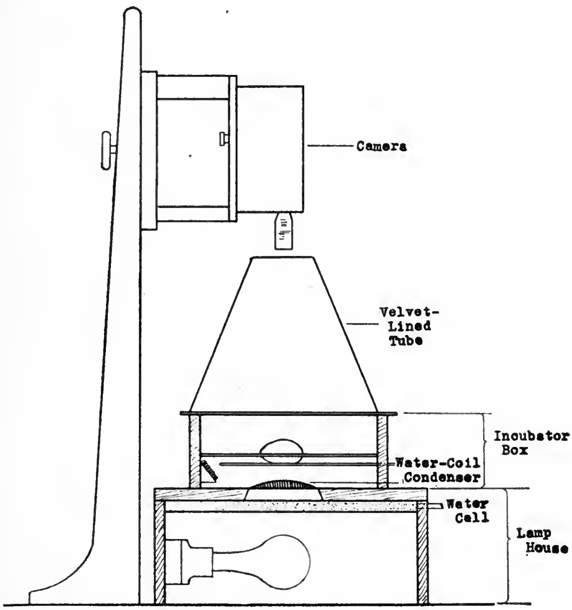

FIG. 1. Incubator box and lamp house.

but slight modification for all the pictures portraying embryonic development by other methods.

The *f*/2.7 4-inch lens was used in making all pictures by transmitted light. Exposures varied on Type *A* Kodachrome film from $^1/_{30}$ second per frame for a fresh egg to 6 seconds per frame for the 20-day-old embryo. This wide range was caused by the increasing opacity of the growing embryo.

Embryo Viewed through Aperture in Egg-Shell.—The second series in the motion picture shows the development of the embryo as seen from the blunt end of the egg. Preparing specimens for this series was extremely difficult, particularly from the 5th to the 13th day of

incubation. Professor Romanoff skillfully removed both the shell and the shell-membranes at the large end of the egg. When that was done it was possible to look within the shell and clearly see the developing embryo. This procedure was followed until the embryo was 13 days old, at which time removal of the inner membrane became so difficult (because hemorrhages were invariably produced) that a new method had to be employed. In its normal state this membrane is white and practically opaque. After considerable experimentation the authors evolved a technic—old in principle but new, it is believed, in application. When painted with an oily substance the membrane became transparent. But to complicate the photographic problem the membrane wrinkled and produced innumerable highlights which precluded any possibility of a clear-cut picture. Any movement on the part of the embryo changed the surface structure and accentuated the undesirable effect. Mineral oil floated upon the invaginated inner shell membrane (at the air-cell space) provided the most satisfactory solution (Fig. 2). In addition to making the membrane transparent the oil formed a plane surface through which it was possible to photograph clearly. By building the oil surface considerably higher than the membrane, embryonic movement proceeded without inducing any photographic difficulties.

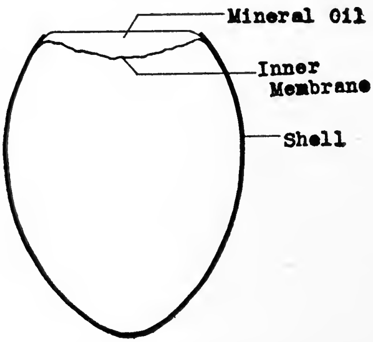

FIG. 2. Mineral oil placed upon the inner membrane to produce transparency.

In Fig. 3 is shown the incubator box, with the egg placed vertically on a black-velvet-covered base. This support was made slightly smaller than the sides of the box to allow free air circulation. The cover was plate glass. Two lights with reflectors were placed approximately 32 inches apart; one, a No. *2* photoflood, was 17 inches from the egg; and the other, a No. *1* photoflood, was 15 inches from the egg. The two lights and the egg were aligned on the same axis at a 30-degree angle to the glass top. This eliminated direct reflection from the oil surface, cast enough shadow to emphasize delicate structural details, and gave an illusion of depth.

The greatest difficulty encountered in filming these activities was

to maintain strict temperature control. If the temperature became too high, embryonic movement was accelerated, and the converse was true with temperatures lower than normal. The reason is obvious when we consider the high radiant energy emitted from the two light-sources. Although it is true that this entire series of pictures was made without controlling radiant energy, if the work were to be duplicated, either water-cells or heat-absorbing glass would be used.

Determining the exact exposure was exceedingly difficult because the reflectivity of the embryo changed from day to day as it underwent structural changes. In general, it may be said that the first few days of development required less exposure than the intermediate stages, and the last few days of growth the least exposure because of

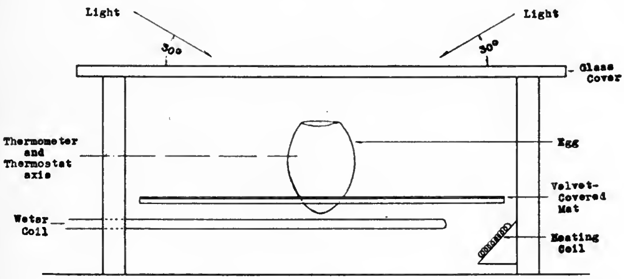

FIG. 3. Incubator box, with egg placed vertically on velvet-covered base.

the formation of down and its high reflecting value. The lens used for these pictures was the 4-inch $f/2.7$, and the exposure was approximately $^1/_{30}$ second at $f/8$.

"Close-ups" of the heart presented an interesting problem in focusing. Since the working distance between the lens and the subject was very short, focusing had to be very critical. However, it is well known that when an egg's contents are placed upon an approximately flat surface sagging of the yolk occurs. Thus, it is obvious that as the yolk slowly receded, the embryo, which was on the top surface of the yolk, moved away from the lens, thus throwing the picture out of focus.

Pictures with Embryo in Watch-Crystal.—The third series, showing the egg's contents emptied into a watch-crystal, presented approximately the same difficulties as did the preceding pictures, with two exceptions—humidity and radiant energy. With much of the egg

content exposed to the air, both evaporation and absorption of radiant heat were increased, thus accentuating the effects noted in the previous series.

Hatching Pictures.—The most tedious series of exposures were those made at the hatching period. Relative humidity had to be maintained at 65–70 per cent to insure a normal hatch. Because of the high humidity, condensation upon the glass cover of the incubator box made photography difficult. Also, the emerging chick was extremely conscious of visible light and often ceased all activity as the exposure was made. However, the greatest difficulty arose because of extreme variations in the hatching time for each individual, for some chicks emerged in ten minutes and some in three hours.

General.—So far as general comments are concerned the motion picture *Where Chick Life Begins* took three months to produce, more than 2000 eggs were used, and five separate originals were made at the same time. It should also be said that, with the exception of certain scenes incorrectly exposed, the fidelity of color reproduction is excellent. At the present writing more than 40,000 persons in all sections of this country and parts of Canada have seen the picture, and more than 500 written requests (from all over the nation) for its use have been refused.

It is this author's opinion that if we exclude the interest inherent in the subject itself, the enthusiastic reception that this picture has received is due more to its reproduction in color than to any other technic involved. Furthermore, if the picture may be regarded as a fair example of what can be done in the biological sciences, the latent possibilities for similar projects are enormous in variety and number.

DISCUSSION

Mr. Kellogg: How much film footage was used?

Mr. Phillips: That is difficult to say, because in addition to the three months for making the picture, there was about a month of experimental work, during which we used probably 400 or 500 feet of film to determine the exposure experimentally. We often had pictures that did not show what we wanted to show, from an embryological point of view, so we had to discard them. So far as exposure is concerned, we lost about 500 or 600 feet and used approximately, as a grand total, about 8000 feet of film.

The film has been shown in a great many schools throughout the country. The Purina Company received four copies and the University one, and Professor Romanoff has shown the film extensively in schools of higher education.

Mr. Roger: I wish to congratulate the makers of this film, Professor Romanoff and Mr. Phillips, for the excellent material we have had the opportunity of seeing.

I have produced a lot of such material myself, not only on embryos but also on living tissue and blood cells, and I realize how difficult it was to get the material together and make the picture. As Mr. Phillips has indicated, temperature and conditions of light, heat, and so on have much to do with the success of the film.

MR. TUTTLE: What was the relative humidity during the incubation period; and how long do the embryos live?

MR. PHILLIPS: The relative humidity was approximately 70 per cent, slightly above the value for normal incubation.

The eggs with the shell opened at one end may be capable of hatching, but in our work we used mineral oil at the opening, which caused suffocation of the embryo in a relatively short period of time. The embryos broken into the watch crystal did not live more than a few minutes, or at the most several hours.

MR. KELLY: The chick's supply of oxygen depends upon a continuous supply through the shell, does it not?

MR. PHILLIPS: Yes. The shell is permeable, as is also the membrane. This allows for interchange of gases.

MR. KELLOGG: How do you dispose of waste products, or render them harmless?

MR. PHILLIPS: Aside from carbon dioxide, the waste is not a large item; it is usually left in the alantoic sac, as it is called, at hatching.

DOCUMENTARY FILM STUDY—A SUPPLEMENTARY AID TO PUBLIC RELATIONS*

A. A. MERCEY**

Summary.—*The success of two U. S. documentary films, "The Plow That Broke the Plains" and "The River," written and directed by Pare Lorentz, has focused new attention upon this type of film. The school of Public Affairs of American University conducts a film course of eight weeks, with screenings, film analyses, and discussions conducted by visiting experts in film-making and film use. The subjects covered are: the newsreel as contemporary historian; the "March of Time" as a document; federal, educational, and scientific films; U. S. Government documentary films; documentary aspects of Hollywood films; foreign documentaries; industrial, sales, and domestic propaganda films. Technical aspects with reference to advances in film production were discussed.*

In addition to regular discussion and study, a number of reports were made on documentary film activities. Among the most important was a complete survey of all U. S. government films.

The emergence of the documentary film as a medium of social expression is a significant development in the evolution of the modern motion picture. Without seeking a definition of this new film form, producers have gone forward and made films of extraordinary social value. The documentary form has developed with amazing speed and success. While film experts indulge in "streamlined" scholasticism trying to define the word "documentary," films have evolved in many parts of the world that transcend the temporary values of the entertainment film, and are making their own definition of the term.

This new form has had a surprising growth abroad both on the Continent and in Great Britain. Its most representative exponent in this country is Pare Lorentz, who made *The Plow That Broke the Plains* and *The River* for the United States Government. The attention attracted to the new form, particularly to the Lorentz films, has given impetus to the study and production of the documentary form.

Definitions of varying refinement, charges, and countercharges

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** School of Public Affairs, American University, Washington, D. C.

hurled at the documentary film have stimulated the curiosity of those working with human equations, especially those engaged directly or indirectly in educational or public relations work.

The course, "Documentary Films Today," was instituted at American University, School of Public Affairs, to round out a constantly expanding curriculum encompassing the various technics used in public relations. The School of Public Affairs' "in-service" training school for government employees is taught by recognized experts in the government. It was for this group that the course was inaugurated.

"Documentary Films Today" was offered for the purpose of giving some direction and guidance along the lines of contemporary documentary production. It was not offered as a technical or production course, but rather as a survey course that would include discussions of technical changes in motion picture production.

Given for a period of eight weeks, the study necessarily had to be both intensive and flexible. In order to dissipate some of the confusion created by pat definitions of the documentary film by the critics, the students were shown films recognized as documentary or as having documentary aspects. Nearly sixty reels, including twenty-one different subjects, were screened, while five guest speakers, acknowledged experts in their field, supplemented the lecture material. By going to the material contained in various documentary films, it was felt that a truer definition of the new film form could be gained. The general scheme of the course ran along the following lines:

The rise and growth of the documentary film.
The newsreel as contemporary historian.
The *March of Time* as a document.
Federal, educational, scientific, documentary, and action program films.
Documentary aspects of the Hollywood film.
Foreign documentary films.
Industrial, sales, and propaganda films.
The film for the future historian.

The opening lecture pointed out by specific example the general distinctions between a Hollywood story film, the regular educational or scientific film, and the documentary film. The general survey was followed by a showing of governmental, educational, scientific, and action program films.

Mr. Fanning Hearon, Director of Motion Pictures of the Department of the Interior, spoke to the class before the showing. He out-

lined various methods of making government films; and following his lecture, conducted the class through the film laboratories of the Department of the Interior. *Hands* by the WPA, and *In the Beginning* by the U. S. Department of Agriculture were outstanding subjects on this program. Other films included those from the Department of the Interior, The Social Security Board, The Federal Housing Administration, and the U. S. Army.

Both *The Plow That Broke the Plains* and *The River* were screened after a lecture explaining problems of production, administration, and distribution. A general outline under the general title, "From Script to Screen," answered questions previously raised by members of the class.

The Adventures of Chico, produced by Stacy and Horace Woodard, was given a pre-release screening for the class in the discussion of documentary aspects of the entertainment film.

Two outstanding modern films were included in the section devoted to foreign documentaries: *Housing Problems*, a British film, by Arthur Elton and Edgar Anspey, and *Triumph of the Will*, a German film of the Nazi festival at Nuremburg, filmed by Leni Riefenstahl.

The Birth of a Nation, D. W. Griffith's classic, and Sergi Eisenstein's *Potemkin* illustrated the documentary aspects of the historical film.

A program of industrial and propaganda films gave the class a general idea of the progress being made in these fields. *Progress on Parade* and *Where Mileage Begins*, both General Motors' pictures and *Voices in the Air* and *Getting Together*, Bell Telephone productions, were screened.

H. S. Fitz, assistant in customer relations of the Chesapeake & Potomac Telephone company, gave the point of view of the industrialist who uses films for winning public favor. Floyd Brooker, now associated with the film project of the American Council on Education, and an accomplished script writer, presented the problems of the educator in regard to new industrial and propaganda films.

The American Way, sponsored by the National Defenders, and *Death to the Open Shop*, made by the United Automobile Workers of the CIO, illustrated a sharp contrast in objectives in the propaganda field.

J. G. Bradley, Chief of the Division of Motion Pictures and Sound Recordings of the National Archives, described to the class the most

modern methods yet devised to preserve films for the future historian. He escorted the class through the motion picture division and explained the facilities for screening, classifying, and preserving films for the Archives. The students also heard Pare Lorentz speak at a Washington forum on the difficulties affecting production of the documentary film.

Since the time of the course was so limited, many important phases of film making of direct and indirect value to documentaries had necessarily to be omitted. Supplemental material given the students, however, included: preliminary and extensive bibliography of film writings; glossary of film terms; condensation of lecture notes; folders, lithographs, and scripts of *The Plow* and *The River;* program notes on the industrial, foreign documentary, propaganda, and historical films; and lists of outstanding newsreels and best films of the year.

A word about the personnel of the class might be of interest. The course included one person who had written a dozen books, one who was formerly instructor of English at the University of Wisconsin, a chief of exhibits of one bureau, a film chief of another, the wife of a high bureau official, and editors and publicity experts from other bureaus. The class was of rather exceptional caliber.

Reports were prepared by the students in lieu of the examinations customarily given in the School of Public Affairs. Included in these reports was a Federal film survey, the first of its kind ever done. This survey includes history, administrative description, and the work of various Federal film units. This report has long been needed and answers a demand by educators and industry for authentic and complete data on the Government's motion picture activity. It is now being edited for final presentation in a form to be announced later.

The course proved unequivocally that a definite need exists for film courses of this kind, which give direction and guidance to students, especially those of adult-education groups, who are working with publicity, educational, or training groups.

The Society of Motion Picture Engineers might well perform a service to the schools by articulating a course giving a definite approach to film study. The need exists for such a course, and the Society would make a real contribution to contemporary thought, if it fulfilled such a mission.

DISCUSSION

Mr. Wolf: Did you limit your work to documentary and propaganda film?

Mr. Mercey: Since the course was only eight weeks long we could take up very little else. We did give some attention to documentary aspects of entertainment films, but there has been so much confused discussion about documentary films that we tried to give what we could to eliminate some of the haze. The course was a part of a series of courses in public relations, so we had to gear the film course to its influence upon public relations, not educational primarily, not entertainment, but the course for which it was designed.

Mr. Wolf: Do *The Plow* and *The River* represent all the government pictures?

Mr. Mercey: No. I mentioned those two because it happened that I was identified with the production and distribution of them. I would advise those who are interested to obtain a complete list from the National Emergency Council, which has a complete list of film units and film sources. Many of the films listed are documentary; some are educational, some are scientific.

Mr. Wolf: Are all these films produced in the government departments—photography, laboratory and studio work, and so forth?

Mr. Mercey: No, the Department of Agriculture and the Department of the Interior both produce films in their own laboratories from the time the script is written until the film is shown. The films we made were not so produced. We hired cameramen on a *per diem* basis and worked in commercial studios. Our work was done in New York commercial laboratories, and some work in Hollywood. There are three ways of making government films: One is through government laboratories such as the Interior and Agriculture Departments have; another by engaging *per diem* employees, and the third, through the contract method, which has been used by the Social Security and Federal Housing and other agencies.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

AN ULTRAVIOLET PUSH-PULL RECORDING OPTICAL SYSTEM FOR NEWSREEL CAMERAS*

G. L. DIMMICK AND L. T. SACHTLEBEN**

A very compact and light-weight variable-width recording optical system has been designed for newsreel cameras. Fig. 1 shows the system as it appears mounted upon a camera and ready for use. It is 6 inches long, 4 inches wide and $3^7/_8$ inches high, and weighs about $3^1/_4$ pounds complete and ready to record. The mounted system shown in the figure extends about 5 inches back from the supporting camera wall. Advanced performance and new design features characterize the system, as it is really a studio recording system[1] compressed to newsreel proportions, embodying the more important recent advances in studio recording optical system design.

Sound negatives made on panchromatic film by this system are freer of distortion and ground-noise than has hitherto been possible with panchromatic film. By exposing the track with ultraviolet light (in the range of 3000 to 4300 Å) irradiation within the emulsion and attendant spread of the developed image are reduced. An improvement is thus obtained in frequency response and waveform, similar to that resulting from recording with ultraviolet light[2] on the special sound recording emulsions used in studios. The aperture plate or mask of the system is designed to produce the Class *B* push-pull form of the variable-width sound-track.[3] As a result, a very substantial reduction in ground-noise is effected without the employment of a ground-noise reduction-amplifier and ground-noise shutter equipment. In addition to this "free" ground-noise reduction, the push-pull form of the track contributes to improved fidelity by effectively suppressing the distortion that occurs with amplitude-modulated high frequencies, such as sibilants, when the normal spread of the negative image is not compensated for in printing. Prints from a single negative having a wide range of density are equal in fidelity and differ only in respect to surface-noise and overall

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 15, 1938.

** RCA Manufacturing Co., Camden, N. J.

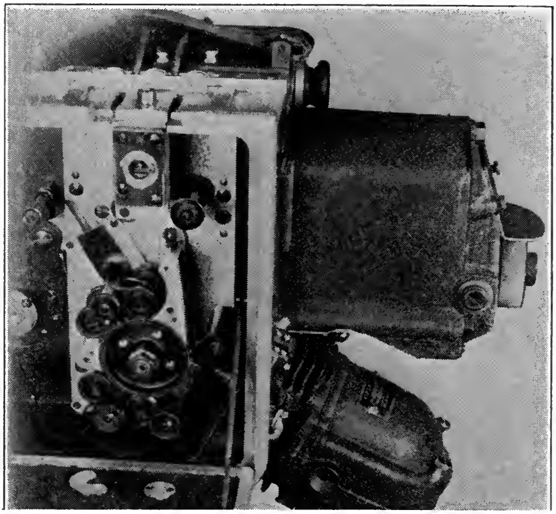


FIG. 1. Optical system as it appears on the camera.

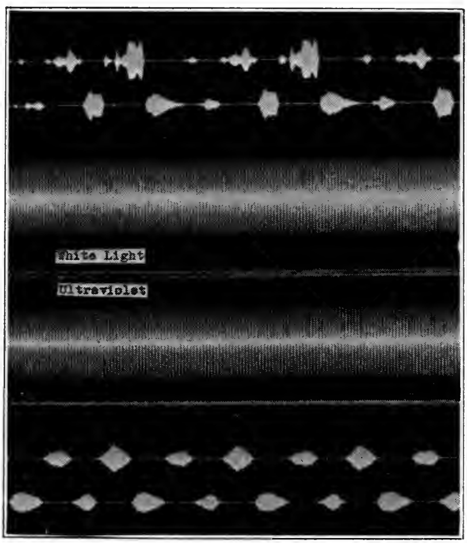


FIG. 2. Enlargements from panchromatic negative tracks made with the system: (*top*) overshot ultraviolet Class *B* push-pull; (*center*) white-light bilateral and ultraviolet bilateral, 6000 cps.; (*bottom*) normally modulated ultraviolet Class *B* push-pull panchromatic.

output. This is important in a single-film system where negative development is determined by the character of the picture and its exposure and the sound-track has to come out as best it can. Fig. 2 shows two speech-waves made by the new system with ultraviolet light, and two comparison tracks, at 6000 cps., made with ultraviolet light and with white light. The tone tracks were purposely made in the bilateral form to facilitate comparison and measurement. The fully modulated Class *B* push-pull track has the standard width of 0.076 inch with a 0.006 septum separating its two portions to assure against overlapping in reproduction. The zero lines connecting the modulation segments are each 0.001 inch wide. The Class *B* push-pull prints from ultraviolet panchromatic negatives have a ground-noise level 50 db. below 100 per cent modulation, which is 12 db. below the ground-noise level of a print from a comparable standard track ultraviolet negative having no ground-noise reduction.

The curves of Fig. 3 show the frequency-response of tracks made with the new system. The upper curve is for negatives made with ultraviolet light, and the lower for those made with white light. Both are printed with ultraviolet light. At full lamp current (4.3 amperes) the ultraviolet negative has a density between 1.0 and 1.2, depending upon development, and it is recommended that

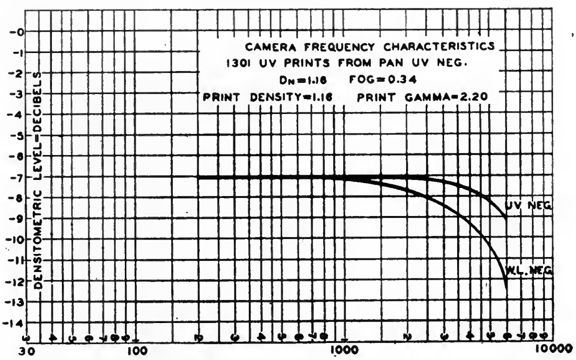


FIG. 3. Frequency-response of ultraviolet prints from panchromatic ultraviolet and white-light negatives made with the system.

the print density be made equal to the negative density, although that is not absolutely essential. When recording with white light, this range of density is obtained with a lamp current of about 3 amperes.

Although the new system is extremely compact, it is complete in all details. All the usual adjustments of lamp, galvanometer, focus, track location, *etc.*, are provided. Some of these features are shown in Fig. 4. The lamp is mounted in a cavity or "lamp house" at one corner of the system and may be adjusted in all three planes and firmly locked in its required position. At full current, 21 watts of power are dissipated in the lamp. Cooling fins are provided on the main part of the casting to aid the escape of the heat. It is found, however, that the large mass and surface of the camera to which the system is secured prevent an appreciable temperature rise from this source even when the lamp is operated for

considerable periods of time. In practice the lamp is interlocked with the camera motor switch and is turned on only while the camera operates. The lamp instantly comes to full brilliance. The galvanometer can be rotated about its vertical axis and locked in the required adjustment by the two opposing screws at the back of the system. A thumb-nut, accessible underneath the system and protected by a guard, adjusts the galvanometer about its horizontal axis. A focus adjustment knob is graduated in thousandths of an inch to permit accurate adjustment of the distance from the objective lens to the film, and may be easily reset to care for any change in thickness of film stock. (The objective moves independently of the slit which is fastened to the main casting.) A lock-screw at the side of the system secures this adjustment after it has been made. The ultraviolet filter is specially mounted so that it may be turned easily to one side

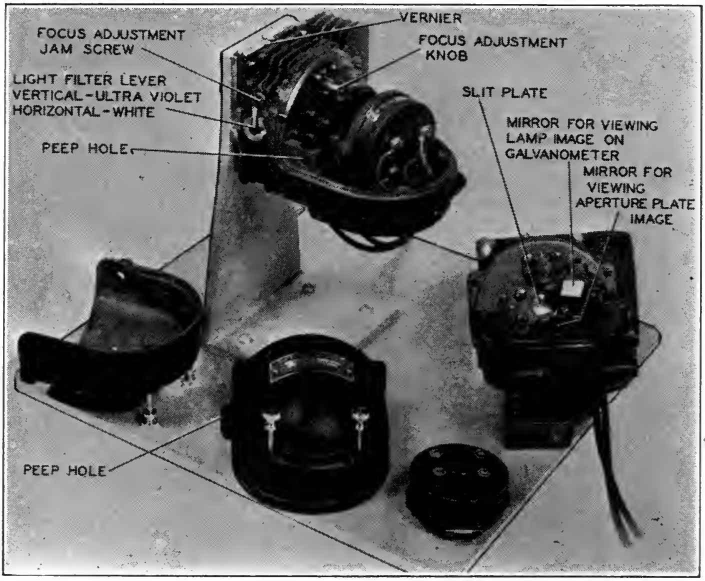


FIG. 4. Optical system with covers and galvanometer removed.

to permit recording with white light, a clear glass plate taking its place to provide the required optical compensation. The provision for white-light recording allows the demand upon the power supply to be reduced in cases of necessity as the lamp then operates at reduced current. The entire system is mounted upon a special plate, a groove in the casting coöperating with a tongue on the plate for azimuth adjustment. The tongued plate is in turn secured to the camera by screws and dowels. Three screws hold the optical system to the plate, by loosening which the system may be moved sidewise for adjusting the track location. A vernier scale on the system coöperates with another on the tongued plate to aid in making lateral adjustments of the system. The azimuth of both the push-pull aperture

plate and the slit are adjusted and dowelled at the factory. A small auxiliary mirror permits the galvanometer mirror to be seen when lamp adjustments are being made, and an auxiliary lens and mirror system permit a magnified view of

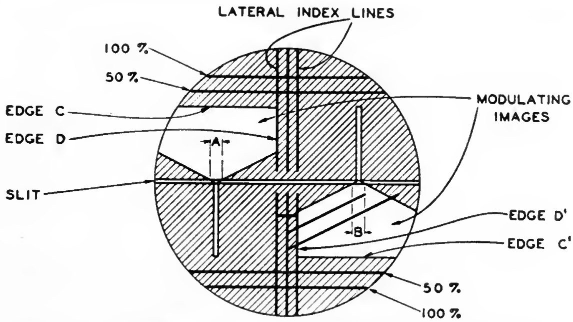
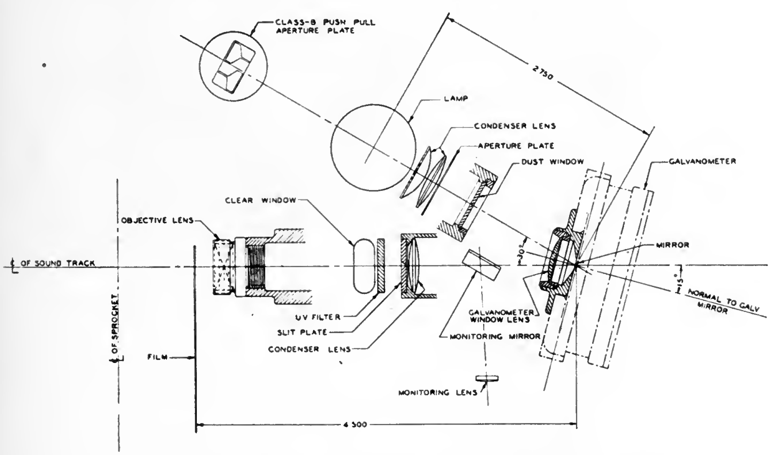


FIG. 5. Diagram showing correct adjustment of aperture plate image on slit (*Note:* lines shown heavy are engraved on slit face).

the slit face when adjusting the galvanometer and judging modulation. Fig. 5 shows the appearance of the correctly adjusted Class *B* push-pull aperture image as seen upon the slit face when looking through the peep lens. The lines marked *50%* and *100%* enable the operator to judge modulation amplitude and set the volume indicator meter on his amplifier accordingly.



ULTRA-VIOLET CLASS-B PUSH PULL RECORDING SYSTEM FOR NEWS REEL CAMERAS

FIG. 6. Schematic diagram of the optics.

The optical system proper is of the same general design as the variable-width studio system[1] but incorporates certain new design features made necessary by its small size. The optical arrangement is shown schematically in Fig. 6. A

new lamp of 4.9 volts, 4.3 amperes rating (21 watts) is used in an *S-8* bulb. The condenser is somewhat faster than those in the studio systems, having a speed of about *f*/1, and is of two elements designed for minimum spherical aberration. It is made of crystal quartz to insure against transmission loss in the near-ultra-violet. The aperture plate is in a dust-proof mounting between the condenser and a quartz dust window. The very limited space requirements make it impossible to image the aperture plate upon the slit by means of a lens mounted axially either preceding or following the galvanometer mirror, and this function is performed by a galvanometer window lens through which the light passes obliquely both before and after reflection from the mirror. This lens is of crown glass and so shaped and placed with respect to the mirror as to perform its function properly. The condenser at the slit is again of crystal quartz and serves to image the galvanometer mirror upon the objective lens. The objective lens consists of four air-spaced elements, corrected chromatically for 3650 and 5460 Å, and having an equivalent focal length of 7.6 mm. and a speed of *f*/2. The image of the slit that

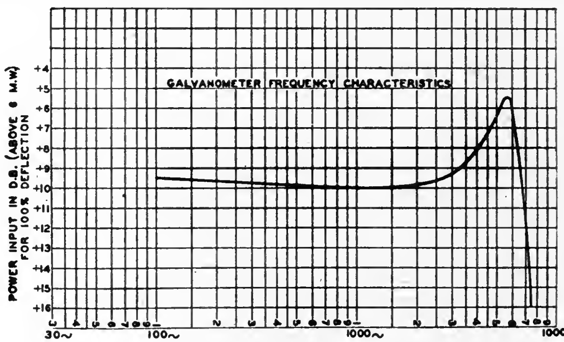


FIG. 7. Frequency characteristic of the galvanometer.

it forms on the film is 0.076 inch long and 0.0005 inch wide. The filter between the slit and objective is of Corning *597*, Red Purple Ultra glass of 2-mm. thickness, and very effectively restricts exposure to the region from 3000 to 4300 Å.

The galvanometer[2] incorporates some recent improvements. Nicaloi is used for both pole-pieces and armature to prevent corrosion and further reduce distortion. The mirror pivot plate has approximately the same coefficient of thermal expansion as glass. It is a stainless nickel iron alloy, and is soldered to the ribbon. The curve of Fig. 7 shows the frequency-response characteristic of the galvanometer. The rise in high-frequency response approximately compensates for film loss to 5500 cps. The required power input at 100 per cent deflection is about 60 milliwatts. Each galvanometer is supplied with a matched capacitor that adjusts the characteristic to the form shown.[3]

Negatives made on the system are printed and re-recorded to the bilateral track form with noise reduction for theater release. The system can easily be converted to produce a bilateral track directly simply by exchanging aperture plates.

Acknowledgment is due the Bausch & Lomb Optical Company for developing the short-focus, wide-field objective used on the system, and further acknowledg-

ment is due R. F. Brady and F. E. Runge for the excellent mechanical design of the system.

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OVERLOAD LIMITERS FOR THE PROTECTION OF MODULATING DEVICES*

R. R. SCOVILLE**

In order to assure the high quality essential to sound recording and reproducing, it is very desirable to avoid overloads, particularly of the recording device. On the other hand, the requirement for maintaining a high signal-to-noise ratio induces operation as near the overload point as possible. With even the most careful monitoring occasional overloading is unavoidable. The effects of overload may be either degradation of quality or actual injury to the recording device. Several forms of devices for the prevention of these have been developed. Their application to the field of sound recording is, however, fairly recent.

One type of amplitude limiter that is now being extensively used in the radio broadcast field[1] prevents excessive amplitudes by automatically changing the loss through a network by an amount that is a function of the amplitude of the signal envelope. Since the loss of the system can not be changed instantly without noticeable distortion, a time delay of the order of 10 to 20 milliseconds between the occurrence of the peak and the correcting action of the system is used. A time delay of approximately 125 to 250 milliseconds is used to restore the system to its normal gain so that the changes are gradual rather than abrupt. Since all portions of a wave are attenuated to nearly the same extent over a given small interval of time, no apparent harmonics are generated to degrade the quality. This kind of limiter will subsequently be referred to as a "peak limiter." A detailed description of such a device is to be found elsewhere in the literature.[2]

A second type of amplitude limiter to be described herein limits peak signal amplitudes to a predetermined value and is without time delay. It has no effect upon signals of lesser amplitude than the critical value and generates harmonics of odd order when "limiting." This will be called a "peak chopper."

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 29, 1938.

** Electrical Research Products, Inc., Hollywood, Calif.

Comparison of Volume-Limiting Methods.—Volume limiting has not up to the present time played as active a role in motion picture recording as it has in radio broadcasting. Motion picture scenes are generally well rehearsed as to volume range, and several "takes" are made. If overload occurs on some takes, others may usually be made that are satisfactory; whereas in radio work it is not always possible to foresee what volumes will arise; and, once "on the air," no retakes are possible. As a result, amplitude limiters have not been used in the majority of motion picture recording sequences. However, there are many cases wherein unusual and unpredictable volume relationships occur when the use of a limiter is definitely valuable. Whether the peak limiter or the peak chopper type of equipment is most suitable depends upon the type of material involved and upon the limitations of the recording medium.

In speech and in certain types of music a small percentage of the peaks may reach amplitudes 15 to 20 db. higher than the average signal amplitude. With many of the recording systems used today, and particularly with variable-density systems, the average recording volume is set approximately 10 db. below the modulator overload point. It is apparent that if a peak limiter that acts upon the signal envelope is used under these conditions, an appreciable reduction of the underlying signal strength will result, which occurs when the peak causes the gain through the device to change. Compression of the signal in this manner results in no unpleasant effects provided the compression does not exceed 3 db. When greater compression is used the loss of volume range may in some cases cause a loss of dramatic expression, or "punch." Thus, instead of this kind of limiting, which is harmonic-free, it may at times be preferable to allow considerable "overload" to obtain the maximum volume. Examples of this sort are gunshots, crashes, hurricanes, battles, or other scenes featuring excitement and commotion. Here the peak chopper proves most suitable, since it prevents damage to equipment and at the same time permits the maximum volume of which the modulating device is capable. On the other hand, in dialog scenes of an emotional nature the harmonics produced by a peak chopper during overload sequences may be objectionable. Here the peak limiter, which automatically reduces gain without incurring harmonics, proves valuable.

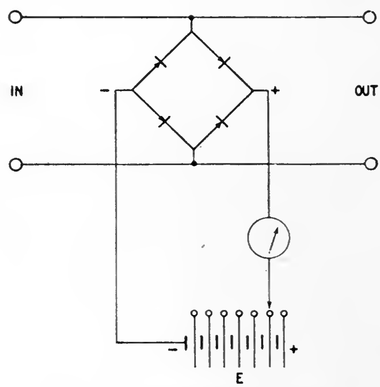

FIG. 1. Peak chopper circuit.

Amplitude limiters should be used in a manner adapted to the recording method employed. With the variable-width system, for example, the harmonics generated with signals exceeding the modulator overload point are somewhat more severe than is the case with the variable-density method. This is because

the space limitations of the sound-track effect a sharp cut-off of both positive and negative peaks in the variable-width system, whereas in the variable-density system the signal is not so sharply cut off at the overload point. There is a considerable range available on the film, even though non-linear, which is of value in reducing the severity of overloads. Owing to this difference, the usual practice has been to operate variable-density recorders with a percentage modulation from 4 to 6 db. greater than in the case of variable-width recorders. Use of the peak limiter with the variable-density system entails the disadvantage that if the limiter operates at the overload point of the valve, a small percentage of the peaks will cause a compression greater than the permissible 3 db., giving a noticeable "pumping" effect and also a loss in the upper volume range. This effect may be avoided by reducing the average volume, but owing to background noise this is not generally desirable. Another alternative is to adjust the peak limiter

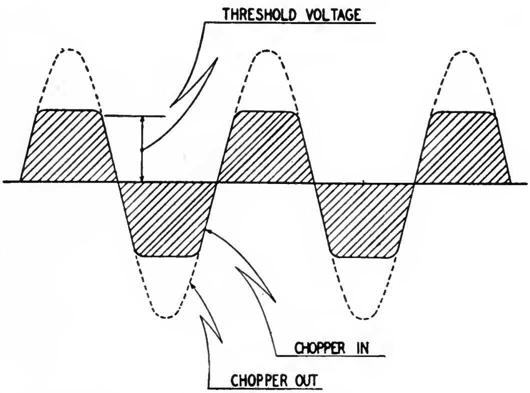

FIG. 2. Showing effect of peak chopper on signal.

to operate at a point 2 to 4 db. above the modulator overload. But in this case the harmonic-free result is largely lost. Still another alternative is to permit a certain amount of overload for the sake of the volume range and guard against damaging signals by using a limiter of the peak chopper type set to operate for signal amplitudes 4 to 6 db. above modulator overload. However, for variable-width recording systems or for radio broadcasting wherein the overload point is sharply defined and may not be exceeded appreciably, the peak limiter or variable-gain type provides a useful function for certain types of speech or music.

A Peak Chopper Equipment.—A peak chopper that cuts off excessive amplitudes without time delay is shown schematically in Fig. 1. Its operation is as follows: A copper-oxide rectifier, or varistor, of suitable design has its a-c. terminals connected across the line and the d-c. terminals connected to a battery having the same polarity as the normal output of the rectifier. Current will flow from the line through the rectifier only when the peak voltage exceeds the battery voltage. During such periods the device acts very much as a short-circuit, so that the line voltage is held down to the predetermined value. For signal vol-

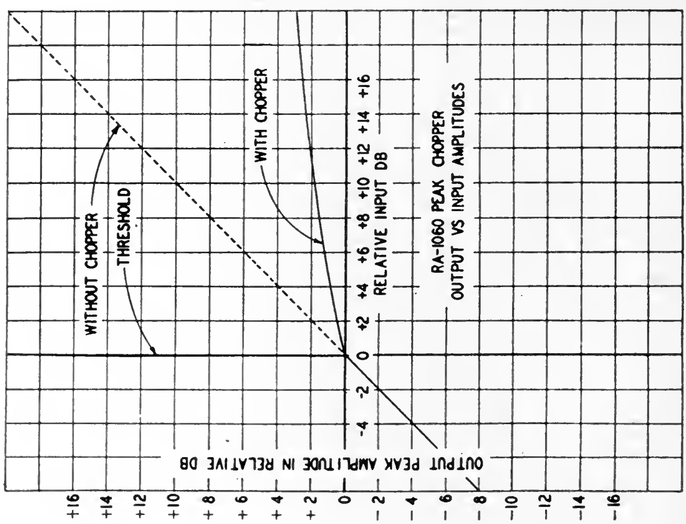

FIG. 3. Relation of output to input amplitude.

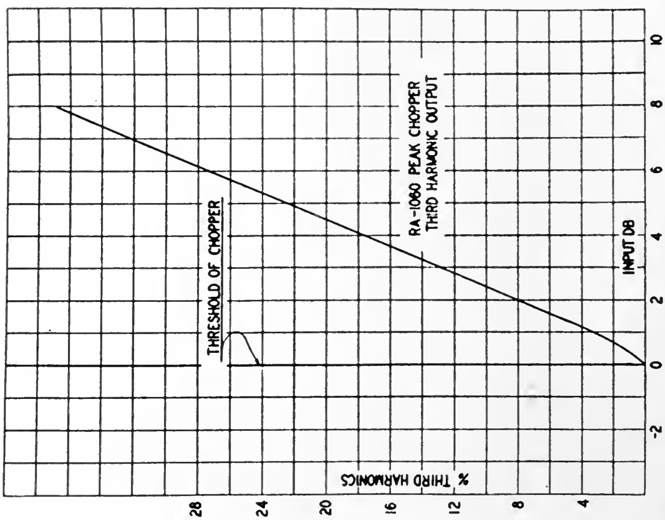

FIG. 4. Third harmonics introduced by chopper for signals greater than threshold value.

tages lower than this value the device has no appreciable effect. Fig. 2 shows the manner in which a sine-wave signal is limited, and Fig. 3 shows the relation of output amplitude to input amplitude. Here a 10-db. increase in input signal above the threshold results in a 2-db. increase in output amplitude. As the threshold value is passed odd harmonics are progressively generated. Even harmonics are not produced in the device. When a peak chopper of this type is used with a modulating device having resonance in the upper audible range, it is advisable to employ a low-pass filter following the limiter. This filter should have its cut-off frequency just below the resonance frequency of the modulator. Third harmonics generated by the limiter and having values in the neighborhood of modulator resonance will thus be incapable of causing trouble.

Fig. 4 shows the third harmonics introduced by the chopper for signals greater than the threshold value. These are of somewhat greater magnitude than those introduced by the film under corresponding conditions. However, by setting the peak chopper to operate at approximately 4 db. above the modulator overload point, when working with variable-density recording, the harmonic generation

FIG. 5. Peak chopper unit.

is held down practically to that contributed by the film, and at the same time protection is afforded to the modulator against further damaging peaks.

With variable-width recording devices the threshold may be set at or slightly above the modulator overload point, since any harmonic generated will be about the same whether generated by the limiter or by the system.

Fig. 5 shows the appearance of a peak chopper of the type described. A low-pass filter is incorporated within the unit for the purpose previously mentioned. A six-position switch shown on the right side of the instrument connects the desired threshold voltage, which is indicated by pressing the push-button shown on the left of the meter. The meter reads voltage on one scale, and overload point in decibels relative to 0.006 watt across 500 ohms on the second scale. As constructed, the threshold may be set so that limiting begins at a value as low as +6 db. or as high as +18 db. relative to 0.006 watt. During operation the meter acts as a milliammeter in the resistor circuit indicating when overload occurs. The degree of overloading obtained is a function of the meter reading (except as modified by the lag of the movement) and may be determined by reference to calibration curves furnished with the unit.

Prior to the use of this equipment with light-valve systems, considerable inconvenience was experienced in ribbon breakage and changes in adjustment. After installation of the peak chopper practically no trouble of this kind that may be attributed to overloads was experienced.

This paper has endeavored to show wherein amplitude limiters have a useful function in sound recording. Of the two types of limiters discussed, one compresses the envelope for excessive amplitudes without harmonic generation but with a time delay; whereas the other type chops off excessive peaks instantaneously, with generation of harmonics. It is felt that the first type is most useful for systems wherein a critical overload point may not be exceeded to any appreciable extent and where such volume compression as results will not be objectionable. For other conditions the peak chopper is found useful for the protection of equipment against damaging overloads.

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[3] HOVGAARD, O. M., AND DOBA, S.: "Higher Program Level without Circuit Overloading" (Presented before the Institute of Radio Engineers, May, 1937; not yet published).

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

19 (Apr., 1938), No. 4

Low Key Lighting May Be as Easy in Color as It Is in Monochrome (pp. 146–151)	W. H. Greene
Agfa Issues Its 35-Mm. Supreme in Spools, Press in Rolls and Packs (p. 150)	
Color in Broadcasting Studied by New Hollywood Television Group (pp. 160–161).	W. L. Prager
Micro Movies Most Efficient Research Tool (pp. 162–164).	P. A. Zahl
European Product Eumig *C4* 8-Mm. Camera Enters American Market (pp. 166–168).	

19 (May, 1938), No. 5

Arnold Devises Semi-Automatic Follow-Focus Finder for Camera (pp. 188–189).	W. Stull
Cine Kodak Secures Added Range in New Eastman Focusing Finder (p. 205).	
Bell & Howell Announces 16-Mm. Projector with Powerful Arc (pp. 206–207).	
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RCA Review

FALL, 1938, CONVENTION

DETROIT, MICHIGAN
HOTEL STATLER
OCTOBER 31, NOVEMBER 1–3, INCLUSIVE

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Headquarters

The Headquarters of the Convention will be at the Hotel Statler, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, who are now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to SMPE delegates and friends, European plan, will be as follows:

One person, room and bath	\$3.00 to \$6.00
Two persons, room and bath	5.00 to 8.00
Two persons (twin beds), room and bath	5.50 to 9.00
Three persons, room and bath	7.50 to 10.50
Parlor suite and bath, for one	8.50 to 11.00
Parlor suite and bath, for two	12.00 to 14.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. Local railroad ticket agents should be consulted as regards train schedules, and rates to Detroit and return.

The following special rates have been arranged for SMPE delegates who motor to the Convention, at the National-Detroit Fireproof Garage (the Hotel Statler's official garage), Clifford and Elizabeth Streets, Detroit: Self-delivery and pick-up, 12 hours, \$0.60; 24 hours, \$1.00; Hotel-delivery and pick-up, 24 hours, \$1.25. Special weekly rates will be available.

Technical Sessions

An attractive and interesting program of technical papers and presentations is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the Large Banquet Room of the Hotel.

Registration and Information

Registration headquarters will be located at the entrance of the Large Banquet Room, where members of the Society and guests are expected to register and receive their badges and identification cards for admittance to the sessions and film

programs. These cards will be honored also at several motion picture theaters in the neighborhood of the Hotel, during the days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual Informal Luncheon will be held at noon of the opening day of the Convention, October 31st, in the *Michigan Room* of the Hotel. On the evening of Wednesday, November 2nd, the Semi-Annual Banquet of the Society will be held in the Grand Ballroom of the Hotel at 8 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Points of Interest

In addition to being a great industrial center, Detroit is also well known for the beauty of its parkways and buildings, and its many artistic and cultural activities. Among the important buildings that one may well visit are the Detroit Institute of Arts; the Detroit Historical Society Museum; the Russell A. Alger House, a branch of the Detroit Institute of Arts; the Cranbrook Institutions; the Shrine of the Little Flower; and the Penobscot Building.

At Greenfield Village, Dearborn, are grouped hundreds of interesting relics of early American life, and there also is located the Edison Institute, established by Henry Ford in memory of Thomas A. Edison.

On the way to Greenfield Village is the Ford Rotunda, a reception hall for visitors to the Ford Rouge Plant. Here are complete reproductions and displays of motorcar design, and representations of the famous highways of the world, from Roman days to modern, are on the grounds surrounding the building.

The General Motors Research Building and Laboratory, located on Milwaukee Avenue, will be of particular interest to engineers visiting the City.

Various trips may be taken from Detroit as a center—to Canada, by either the Ambassador Bridge or the Fleetway Tunnel; to Bloomfield Hills, a region of lakes; Canadian Lake Erie trip from Windsor, Ontario; to Flint, Michigan, another center of the automotive industry; to Milford, General Motors' Proving Grounds; and to the Thumb of Michigan Resort Beaches. The City contains also a number of beautiful parks and golf courses.

SOCIETY ANNOUNCEMENTS

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

CHICKAMOTO, T.
Makaweli,
Kanai, T. H.

DICKELY, F. C.
Altec Service Co.,
2111 Woodward Ave.,
Detroit, Mich.

FORBES, E. H.
210 W. Montcalm St.,
Detroit, Mich.

GROB, E. F.
3 Chesterton Flats,
Manion Ave.,
Rose Bay,
Sydney, Australia.

HARRIS, W. M.
United Detroit Theater Corp.,
1600 Stroh Building,
Detroit, Mich.

JUDSON, F.
134 North Hobart Blvd.,
Los Angeles, Calif.

KAPILA, P. N.
RCA Photophone (India) Ltd.,
Prospect Chambers,
Hornby Rd.,
Bombay, India.

KRULISH, J. A.
63-01 Alderton St.,
Elmhurst, Long Island,
New York.

McGLINNEN, E. J.
19303 Pennington Dr.,
Detroit, Mich.

MALHERBE, E. G.
National Bureau of Educational and Social Research,
Union Buildings,
Pretoria, South Africa.

MATTHEWS, J. G.
10845 Wellworth Ave.,
West Los Angeles, Calif.

MILGROVE, J. D.
17 Kambala Rd.,
Bellevue Hill,
Sydney, Australia.

MINTERN, M.
SS Manhattan
U. S. Lines, 1 Broadway,
New York, N. Y.

MORTENSEN, A.
316 M. & M. Bldg.,
Houston, Texas.

PANCHOLI, R. M.
Empire Talkie Distributors,
Heera House,
Sandhurst Rd.,
Bombay 4, India.

SIMMONS, E. E. JR.
California Institute of Technology,
Pasadena, Calif.

SINGH, U.
Empire Talkie Distributors,
Chandani Chowak,
Delhi, India.

SMITH, M. A.
Box 68, Balboa Heights,
Canal Zone.

STRALEY, W.
3725 Warwick Blvd.
Kansas City, Mo.

TRECELLAS, L. K.
57 Pollman Court,
Streatham Hill,
London S. W. 2., England.

THOMPSON, C. J. P.
Mariners, Christchurch Rd.,
Virginia Water,
Surrey, England.

VAVRINA, E.
Prague V,
Czechoslovakia.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

BRADBURY, H. D.
411 Fifth Ave.,
New York, N. Y.

BREITENSTEIN, S.
198 Johnson Ave.,
Teaneck, N. J.

BROWN, R. C.
1540 Broadway,
New York, N. Y.

BURNS, R. P.
3034 Leland Ave.,
Chicago, Ill.

COOK, A. W.
34 Hayes St.,
Binghamton, N. Y.

PESCE, J. S.
RCA Manufacturing Co.
Camden, N. J.

STRONG, L. D.
908 S. Wabash Ave.,
Chicago, Ill.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXXI **AUGUST, 1938** **Number 2**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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PROGRESS IN THE MOTION PICTURE INDUSTRY*

REPORT OF THE PROGRESS COMMITTEE

Summary.—*This report of the Progress Committee covers the year 1937. The advances in the cinematographic art are classified as follows:*

(I) Cinematography: (A) Professional and (B) Substandard; (II) Sound Recording; (III) Sound and Picture Reproduction; (IV) Publications and New Books; (Appendix) The Japanese Motion Picture Industry; Progress in Germany; Progress in Great Britain.

The most notable advances recorded during the past year appear to have been in the production of new panchromatic emulsions for professional cimematography. One emulsion has resulted in additional negative speed without any consequent increase of grain size. Another new emulsion, intended for newsreel use and work under adverse lighting, has from three to four times greater speed than standard super-sensitive panchromatic films.

In the field of substandard cinematography the popularization of color has advanced rapidly coincidentally with improvement in processing of color-films.

In the field of sound recording there is little to report in the way of advances in equipment, the year's activities being largely confined to the consolidation of advances previously reported for 1936.

The modernization of theaters has progressed satisfactorily, especially in the matter of installation of the newer two-way horn systems announced in last year's report.

In the projection field there is little to report in the way of new equipment, either for sound or picture projection. The Committee is including for the first time this year material describing theater lighting and marquee illumination.

The Committee wishes to thank the following companies for supplying materials and photographs for the report: Ampro Corporation; Bell & Howell Co.; Eastman Kodak Co.; Electrical Research Products, Inc.; General Electric Co.; General Service Studios, Inc.;

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 15, 1938.

General Radio Co.; Mole-Richardson Co.; Paramount Pictures Corp.; Victor Animatograph Corp.

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V. E. MILLER

SUBJECT CLASSIFICATION

(I) CINEMATOGRAPHY

(*A*) *Professional*

The year 1937 has seen some very definite progress in the field of professional motion picture photography.

(1) *Emulsions.*—Perhaps the outstanding advance for the year has been made by the Agfa Ansco Corporation, who developed and marketed two new and very fast panchromatic negatives that have proved almost revolutionary, in that they have "de-axiomized" the old belief that added negative speed always meant increased grain size. Conversely, their new negatives, with a very great increase in speed, have maintained and even lessened the grain size. The Agfa Supreme is a new product having twice the speed of standard supersensitive panchromatic emulsions. It retains to the full extent

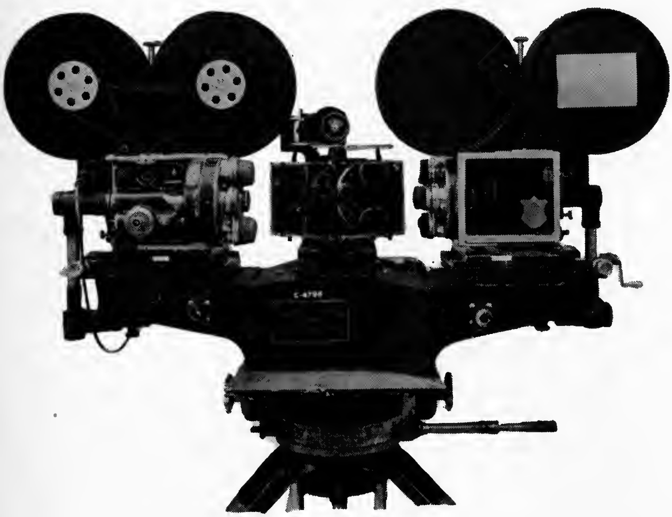

FIG. 1. Dual screen transparency camera.

such essential qualities as keeping stability, color balance, and extremely fine grain which, heretofore, were impaired by increased speed. It provides the production cameraman with a means of reducing working camera apertures, with a consequent increase of definition and better photographic quality. It minimizes the problem of character grouping which, in the past, has been restricted by shallow focus. It increases the efficiency, realism, and scope of process projection work, thereby enabling economy to producers. In general, it represents a major achievement in research and emulsion manufacture by providing the industry with a medium of increased latitude and quality.

The Agfa Ultra-Speed Pan is intended for newsreels and adverse light conditions. It has from three to four times greater speed than standard supersensitive panchromatic material. It possesses full keeping stability and provides the industry with a means of obtaining photographic results under adverse conditions heretofore impossible. It is of particular value for night scenes photographed under ordinary artificial illumination and for night scenes of large area with special artificial illumination. It increases economy in production by permitting work in poor light thereby increasing the working day. It provides newsreels with an efficient material under conditions outlined above.

The Eastman Kodak Company brought out two fine-grain duplicating films,[1] negative and positive, that are well worthy of note in that they bring duplication quality much closer to the original. Since speed is not especially essential in duplication, the Eastman Company have concentrated upon grain reduction, resulting in an extremely fine grain so necessary for ideal results. Duplicate negatives from lavender positives, using this new fine-grain stock, are almost exact replicas of the original, retaining their texture and quality. These new stocks have proved highly adaptable to projection work, because of their lack of grain and great latitude.

(*2*) *Cameras and Accessories.*—No new cameras have been developed during the year, but the Twentieth Century-Fox Camera, described last year in the JOURNAL, having successfully photographed eighteen productions since its inception, still leads the field. It is of interest to note that ten similar cameras are now in course of construction for Twentieth Century-Fox, the first to be delivered in April. Since this camera will be made available to other studios, its use by the studio of origin will be under careful scrutiny during the coming year.

The semi-automatic follow-focus finder, as used more or less on all blimped cameras, has been carried to a high degree of completion at MGM Studios, where every camera is so equipped. Paramount also has several of similar design, as no doubt have other studios, but MGM, through their chief cinematographer, John Arnold, have stressed the importance of this tool. The improved finder is void of lost motion, exactly correlating the focus and fields of the camera and finder lenses, respectively, greatly facilitating the speed and accuracy of the camera crew.

A rather unique set-up is the dual screen transparency camera, devised by Farciot Edouart and the Transparency Department of

Paramount Studio (Fig. 1). It augments projection background work by doubly widening the process background, and permitting its use by simultaneous projection on two screens of this doubled area. Twin cameras are mounted in such a way that they photograph a background of double the ordinary width as reflected on surface reflectors adjusted to simulate a single background. This makes possible, for instance, continuity of action across two screens (or a screen of double width); the exact alignment of horizon levels on the two screens; no lap-overs at their junction; and the maintenance of the size of actors or objects found in the single screen.

Although designed for and adapted to Technicolor and cartoon work, the new Disney multiplane camera is an outstanding achievement, with possibilities in the black-and-white field, particularly in title work. The camera, specially designed, is mounted to shoot vertically downward from the top of a chassis carrying several planes on which the action is depicted, each supplementing the others as desired. The machine is of extreme accuracy; each of the planes may be moved separately or jointly, with vernier calibrations assuring exactness of duplication when necessary. Since each plane may be lighted separately, or moved closer to or further from the shooting lens, or at different speeds, some of its possibilities are evident. It does the work in the Disney Studio of a Special Effects Department in the Major Studios, plus a speeding up of production due to the photographing of the several planes simultaneously. Because of the various planes, truer perspective may be achieved as the camera "dollies" up to or away from the "key" plane, while "atmosphere" is varied at will by altering the focal distances of the planes. Another of its manifold uses is the substitution of a "projection" background for one of the planes, enabling the operator to double in effects (shimmer, ripples, heat waves, *etc.*) in conjunction with the other planes. *The Old Mill* and *Snow White* contain examples of this multiplane work.

(*3*) *Stage Illumination.*—The two Mazda lamp manufacturers announced as of March 1st two new photoflash lamps, the *No. 7*, which incorporates a fine aluminum wire and a small amount of foil in the *A-15* bulb; and the *No. 15*, which employs special heat-treated foil in the *A-19* bulb. The *No. 7* has a total light output of 22,500 lumen-seconds and the *No. 15*, 30,000 lumen-seconds. Because of the aluminum wire and the specially treated foil the light-output *vs.* time relation is much broader than the older, regular foil lamps. The

advantage of this broader peak characteristic is to improve the reliability of obtaining pictures when the lamps are used with synchronizing equipment. The broader flash also affords more practical synchronism with focal-plane type shutters. The *No. 7* lamp, being in the *A-15* bulb, has also the advantage of greater compactness.

The Libbey-Owens-Ford Glass Company of Toledo, through coöperation with the Nela Park Engineering Department of the General Electric Company and with the Technicolor Motion Picture Corporation, has made available a special blue glass filter which, when used with incandescent lamps of the *CP* type, corrects their light so as to give correct color with the Technicolor process. The light emitted by incandescent lighting equipment employing the *CP* lamps and these filters is such a close duplication of daylight that subjects can be illuminated with a mixture of this filtered light and daylight or arc light and no difference in the color can be detected. The filters consist of a base of medium-blue glass upon which has been sprayed a magenta-blue enamel, which is subsequently fired into the glass. This process has the advantage also of greatly strengthening the glass so that the likelihood of breakage is extremely remote. These filters had their first general introduction in the photography of *The Goldwyn Follies* and are being used in subsequent productions.

(*B*) *Substandard*

Keeping step with the pace set in immediately preceding years 1937 has actively contributed to advancements in the substandard field of cinematography. Much new equipment of improved design has made its appearance, both of domestic and European manufacture. Both 8-mm. and 16-mm. equipment retain their popularity in America, while in addition to these sizes the 9.5-mm. equipment continues its popularity abroad; although it is not favorably received in this country. Sixteen-mm. sound equipment of improved and simplified design has done much to popularize 16-mm. film in the educational, entertainment, and advertisement fields. Sound projection equipment of satisfactory quality, while still somewhat too expensive to find favor with the average amateur, is being slowly reduced in price and is now beginning to attract the attention of the advanced amateurs.

For commercial entertainment 16-mm. film has not found exten-

sive use in America as yet; abroad in England and the Continent numerous theaters operate regularly with 16-mm. film. Gaumont British are currently releasing productions on both 35-mm. and 16-mm. widths. Except for the late productions of a few major producers, 16-mm. library films are restricted to old pictures of independent producers.

Improvements in sound recording technic, advancements in the art of animation, refinements, and simplification of projection mechanisms have contributed in popularizing 16-mm. film for educational purposes. The field of visual education has grown so rapidly that producers of educational films have not been able to keep up with the demand for them. In science, in medicine, in industry, and in sport this substandard film medium is proving more and more important.

FIG. 2. Bell & Howell 8-mm. camera.

(*1*) *Films.*—Superpan Negative, new type, replaced the former Superpan manufactured by the Agfa Ansco Corporation. The new film is approximately twice as fast as the former Superpan. The film has the same type of color-sensitivity and latitude, and the grain size has not been increased.

Dufaycolor film has been improved. The reseau has been made finer, resulting in a decided improvement in appearance of the screen pattern and assuring sharper definition. Dufaycolor has been made available abroad for 9.5-mm. cameras. The film is supplied in magazines in 30-ft. lengths.

(*2*) *Cameras.*—The new Cine Kodak model *E* was brought out by the Eastman Kodak Company. It is a moderately priced camera equipped with *f*/3.5 lens and variable speeds of 16, 32, and 64 frames per second. It takes either 50-ft. or 100-ft. rolls of film.

Bell & Howell Co. introduced a new "streamlined" 8-mm. camera (Fig. 2), differing from former models in the design of the exposure dial and in the shutter release mechanism. The new models incorporate single-frame exposure devices as standard equipment.

Agfa abroad introduced the 8-mm. Movex. The camera is of the

magazine type, each magazine holding 33 ft. of 8-mm. film. It is equipped with an $f/2.8$ fixed-focus lens.

The model *F* 16-mm. Siemens camera, introduced by Siemens-Halske, is of the magazine type and follows the well established line of Siemens equipment. It has interchangeable lenses and the lenses are provided with focal lengths from 20 to 200 mm. The camera has

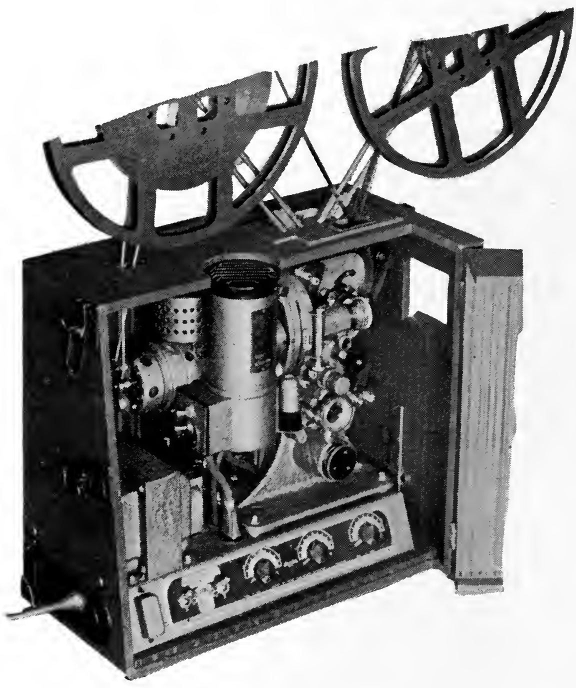

FIG. 3. Victor model *38*.

four speeds, 8, 16, 24, and 64, and is equipped with a single-frame device for making still pictures. This camera is being imported for the American market. Siemens also introduced an 8-mm. camera taking 25-ft. spools of double-*8* film. The speed control is coupled with the aperture. Four speeds have been provided. The camera is also equipped with a single-picture device.

Zeiss Ikon abroad brought out the Movikon *8*. The camera is equipped with an $f/2$ Zeiss lens. Features of the camera are interchangeable lenses and film speeds of 8, 16, and 64 frames a second.

This camera is said to be the first precision-built camera to accommodate both single 8-mm. and double-*8* film.

Ditmar, a 9.5-mm. camera made in Austria, was announced to the European trade. The camera is equipped with an $f/2.9$ Cassar lens, has an interchangeable lens mount and two speeds. This Company also introduced a new 8-mm. camera.

Pathé abroad introduced a new 9.5-mm. camera, equipped with a fixed-focus $f/2.5$ lens. The camera is claimed to be unusually silent and is said to be the smallest movie camera made.

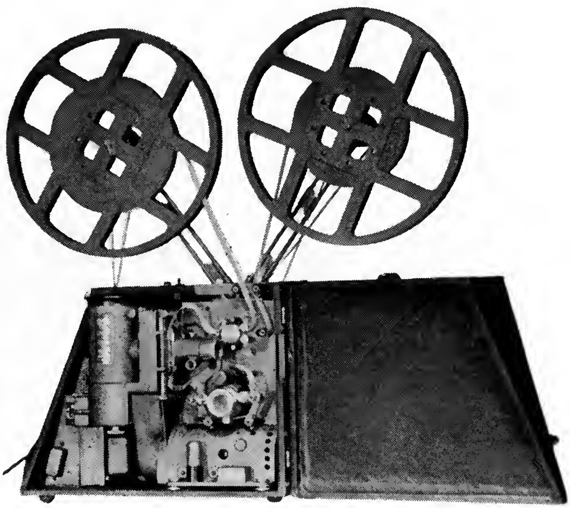

FIG. 4. Victor model *33*.

(*3*) *Projectors*.—The Animatophone model *38* (Fig. 3), a 16-mm. sound projector, was introduced by the Victor Animatograph Corporation. It is regularly equipped with two 12-inch magnetic type speakers and delivers 30 watts of undistorted output. The use of permanent-magnet speakers makes it possible to use four speaker units when desired to insure better sound distribution. The equipment is suitable for large auditoriums. In addition, a mixing panel has been provided for educational purposes and classroom use, which permits the instructor to add his own comments by eliminating the sound without having to readjust the volume or tone of the amplifier. Victor Animatograph Corp. also brought out a model *33* Animatophone (Fig. 4), a small, compact, low-priced 16-mm. sound projector.

The speaker and projector are combined in one unit for portability. A 5-watt output amplifier is provided. The lamp house has spira-draft ventilation and is adaptable to all standard prefocus projection lamps.

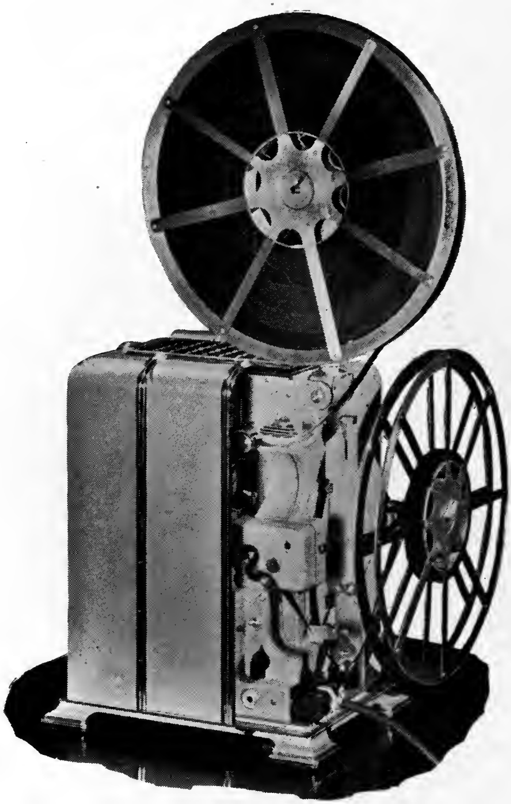

FIG. 5. Sound Kodascope Special; set up with 1600-ft. reels.

The sound Kodascope Special (Fig. 5) was introduced by the Eastman Kodak Company. This instrument represents years of research in the development of 16-mm. sound equipment and is a radical departure from the usual 16-mm. sound projection apparatus. Operation of the equipment is extremely simple. An automatic loop-forming mechanism assures synchronism. The scanning-drum shaft carries a flywheel and is driven by viscous coupling. In this

way any possibility of high- or low-frequency modulation is avoided. The pull-down is of the single-claw type, and is designed to have low acceleration at both ends of the stroke. The entire mechanism is enclosed in an oil-bath which insures long mechanical quietness. Films may be projected at 24 or 16 frames per second. An $f/1.6$ 2-inch lens is supplied as standard equipment, and a 4-inch $f/1.6$ lens is also available. Reel arms are provided for 1600-ft. reels. A lever changes the focus of the high aperture scanning-beam so that re-

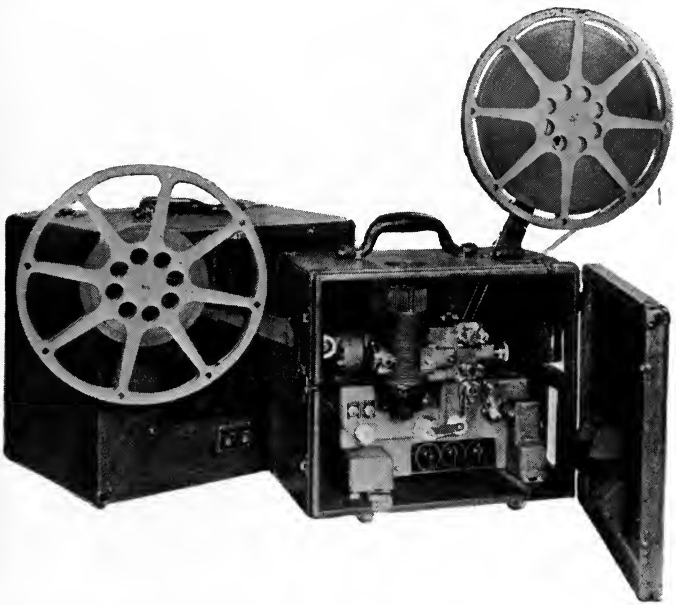

FIG. 6. The *138-J* Filmosound and the *138-J* with booster amplifier.

versible films, positive prints, or reversible duplicates may be projected without loss of frequency response. The pre-amplifier is installed in the base of the Kodascope and the power amplifier is contained in the speaker assembly.

The Filmosound model *138*, manufactured by Bell & Howell, has been much improved. A reversing switch has been provided as well as a still-picture clutch. In addition to the single-case machine, a two-case model is now offered, one of the cases being the projector blimp and the other housing the loud speaker. For installations where volume greater than can be provided by the *138* model is necessary,

a special speaker case housing a power amplifier is available (Fig. 6). With this arrangement sufficient volume can be obtained for large auditoriums. The model *120* Filmosound is also now equipped with a reverse switch and still-picture clutch. A new amplifier for the equipment has been designed which provides 25 watts of undistorted output. High-fidelity permanent-magnet dynamic speakers are now furnished with this equipment. The power output of the Filmosound model *130* (Fig. 7) has been increased to an output of

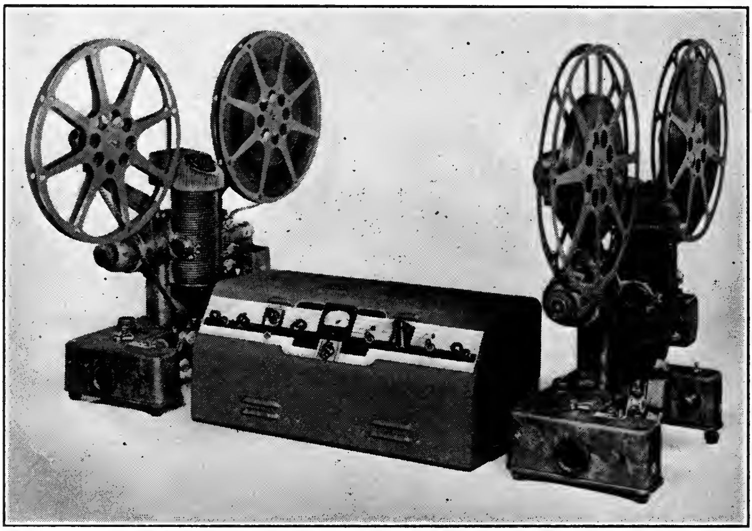

FIG. 7. Model *130-D* Filmosound.

50 watts when two speakers are used. The volume is said to be more than sufficient for average auditorium use.

The Ampro Corporation brought out a new 16-mm. sound projector, model *L* (Fig. 8). The projector is equipped with a barrel type of shutter and a 750-watt lamp. It provides sufficient illumination for auditorium projection. The amplifier output is 40 watts undistorted power to two speakers.

Standard Projectors, Inc., introduced a new 16-mm., 750-watt projector employing a barrel type of shutter and an *f*/1.6 lens. An interesting novelty is the adjustable gate tension which makes it possible to project any type of film with safety.

Eastman Kodak Co. introduced an 8-mm. Kodascope model *50.* This is a projector in the medium-price range.

S. P. Equipment, Ltd., brought out a new 16-mm. sound projector making use of an intermittent sprocket instead of the customary claw for moving the 16-mm. film. The film is moved over a 6-tooth sprocket which insures smooth film operation even with damaged perforations.

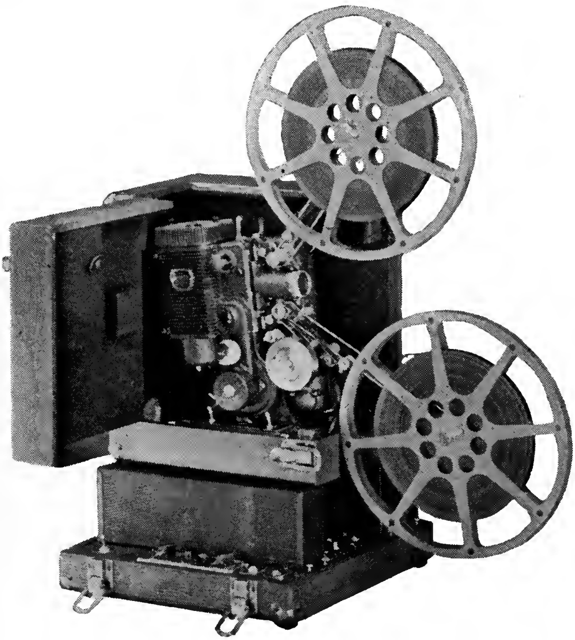

FIG. 8. Ampro model *L* sound projector (16-mm., 750-watt).

Abroad, Paillard-Bolex improved their line of universal projection equipment for projecting interchangeably 8, 9.5, and 16-mm. films by introducing the interchangeable condensers so that maximum illumination would be obtained with whatever width of film was being used.

Agfa abroad introduced the Movector *8.* A 200-watt lamp with specially designed condensers is claimed to give excellent illumination.

(*4*) *Miscellaneous.*—A cine exposure meter was brought out by Weston. The meter has a viewing angle of 25 degrees, which is approximately that of a 1-inch lens.

A new wide-angle lens for all 16-mm. Cine Kodaks was made available by the Eastman Kodak Company (Fig. 9). The lens has a focal length of 15 mm. and an $f/2.7$ lens in a focusing mount. The focusing scale is graduated down to 6 inches which makes the lens especially useful for close-up cinematography.

A new auxiliary condenser to be used on all current model Bell & Howell projectors, except the model *130*, was brought out by Bell and Howell (Fig. 10). This condenser is inserted in a slot provided in the rear of the regular condenser in the equipment. Its use is said to increase the illumination as much as 56 per cent when wide-angle lenses or lenses of wide aperture are being used.

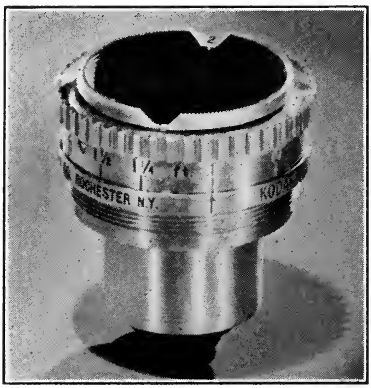

FIG. 9. Kodak 15-mm. $f/2.7$ lens.

A new exposure guide for Kodachrome film was brought out by the Eastman Kodak Company (Fig. 11) to assist users of this film in obtaining correct exposures.

(II) SOUND RECORDING

(*1*) *General.*—The trend toward mobile recording equipment has been brought about by a desire to use equipment interchangeably for stage and location work, and by the advantages of having channel-operating personnel more intimately associated with stage production. It is further emphasized by the new sound-stage construction that makes decentralization of the recording plant more necessary. Twentieth Century-Fox have added a number of channels employing trucks in which the recording equipment is located. A portable mixer is carried to the set, and connects to the truck for recording. Metro-Goldwyn-Mayer have added stage units, dolly-mounted, which contain complete channels from mixer to recorder. These are operated on the stage adjacent to the set, and require only connection to the 110-volt a-c. lines for power. General Service Studios mount their recording equipment in trailers (Fig. 12), and carry a portable mixer unit to the set. In addition, they have trailer-mounted re-recording machines that may be used in conjunction with either fixed or mobile recording channels for re-recording. Such a set-up usually

involves the use of a review room or small stage for monitoring and projection facilities. Paramount employs stage units or "teawagons" on the set, connected to a central recording building housing the recorders and associated equipment.[2]

Increased emphasis has been placed upon recording methods providing improved quality and greater volume range. Methods include: non-slip printing; intercutting of variable-width and variable-density sound-tracks; the use of track-squeezing devices with variable-density recordings; and the application of a new form of pre- and post-equalization to variable-density push-pull records. The latter method was introduced by Metro-Goldwyn-Mayer, and

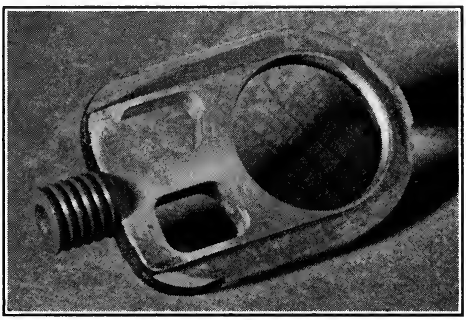

FIG. 10. Magnilite condenser.

results in additional noise reduction, decreased intermodulation, and elimination of background noise modulation or "hush-hush."

Multichannel recording for musical scoring is an interesting variation of the usual scoring technic. Separate channels are used for the soloist, orchestra, or chorus. As much acoustic separation as possible is employed between the different microphones. This method makes it possible to record all parts simultaneously, effecting some recording economies. The separate tracks are then available for re-recording in the usual way. In exceptional circumstances, notably in Universal's *100 Men and a Girl*, separate channels were used to record different instrumental groups of an orchestra.

(*2*) *Equipment.*—A number of novel devices based upon advanced engineering principles have been announced during the past year. Electrical Research Products, Inc., have developed a negative playback amplifier suitable for reproducing directly from film negatives[3]

(Fig. 13). Applications include editing and re-recording newsreels, and studio facilities for reproducing from negatives when it is desired to compare sound quality from negatives and prints.

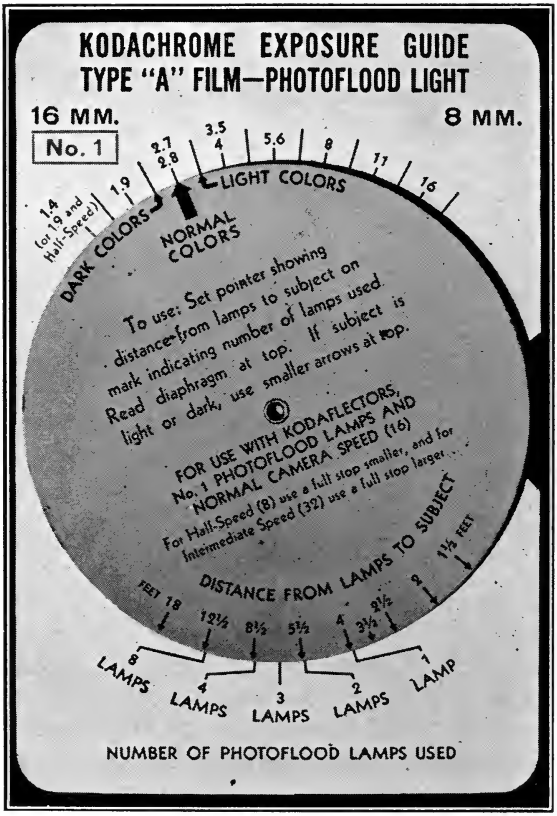

FIG. 11. Kodachrome exposure guide for type *A* film in photoflood light.

A new type of hill-and-dale recorder utilizing reverse feedback was announced by Bell Telephone Laboratories.[4] In addition to improved quality for processed recording materials, it provides excellent recordings on direct materials for immediate playback. It has wide application for scoring for playback work.

RCA has developed a new modulator system capable of recording

variable-width or variable-density tracks, either standard or push-pull.[5]

A large number of RCA recorders of both studio and portable types manufactured and in service before the advent of ultraviolet recording and the bilateral shutter[6] were equipped to include these recent developments.

The non-slip[7] printer developed by RCA has come into more general use during the past year. Printers utilizing the principle are being produced commercially and the industry has come to use non-slip prints as the standard of comparison. A motor-driven blooping shutter has been added to a number of RCA printers with very satisfactory results.

FIG. 12. Trailer recording unit.

Class *A* push-pull recording[8] was demonstrated very successfully in a series of tests. Due to its numerous advantages, such as cancellation of even-harmonic distortion, elimination of splice noises, speeding up of noise-reduction shutter action, and elimination of shutter thump usually resulting from this increased speed of action,

etc., a number of recordings have been made under routine studio conditions.

The development of the modulated-carrier oscillator[9] has provided an excellent means for determining the optimal processing conditions for variable-width recordings. Continued use of this oscillator in making recordings for a number of processing laboratories during the past eighteen months has demonstrated the value of this instrument.

FIG. 13. Negative playback unit.

A newsreel type of recording equipment was introduced by RCA. This equipment provides class *B* push-pull recording with ultraviolet light on the identical film upon which the picture is photographed. The recording optical system is mounted on the rear of the motion picture camera. Although light in weight and simple to operate, this equipment includes features heretofore obtained only in studio type apparatus, and produces results that compare favorably with studio recordings.

(3) *Accessories.*—The General Radio Company brought out a new power-level indicator, a vacuum-tube type rather than copper-oxide, which they had previously manufactured (Fig. 14). This instrument has a high-speed meter with a delay circuit so that sudden peaks are not lost but are indicated quite faithfully. A delay circuit makes the return swing much slower than that provided by the meter movement itself, with the result that the indication seems to float on peaks and gives an accurate monitoring indication without the erratic motion characteristic of high-speed instruments.

The Mole-Richardson Co. has developed the type *103-B* microphone boom and type *126-B* microphone boom perambulator (Fig. 15). The wide use of the new light-weight microphones indicated that it was advisable to use duralumin and light-weight aluminum alloys in

FIG. 14. Type *686-A* power-level indicator.

the construction of the new boom head. In analyzing the causes of noise in boom operation it was decided to eliminate the use of stranded-wire cable, to put all moving parts on rolling rather than sliding contact surfaces, and as the design was developed a means was worked out of supporting the telescoping tubes on rubber rollers. Incorporated in the design as an integral part is the complete gunning device which rotates the microphone through 280 degrees. The weights of the various components are indicated in the specifications. The microphone boom perambulator is of the three-wheel type, which facilitates maneuvering, and is designed so that the wheel tread can be narrowed to pass the perambulator through a 30-inch door and can be widened to provide a substantial working base. The column and supporting platform for the operator are simultaneously elevated or lowered by means of a screw-operated lifting system. Careful attention has been given in the design of the perambulator to the elimination of all extraneous noise.

Other equipment introduced during the past year that tends to improve or facilitate recording includes the miniature condenser transmitter, high-quality moving-coil head-sets for monitoring on the set, and various forms of the peak volume indicator.[10,11] All these devices require some change in studio operating technic to realize their full advantages.

Routine transmission testing has been greatly facilitated by the use of recording types of gain-measuring apparatus.[12] This method gives records that are useful for immediate inspection and subsequent filing, and minimizes maintenance costs.

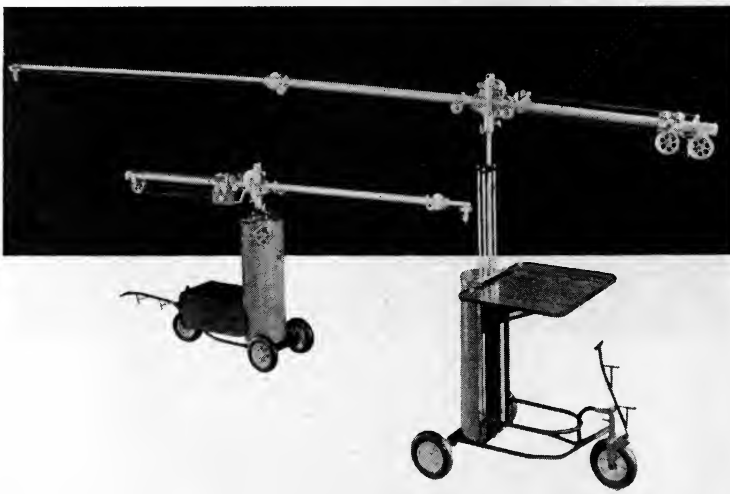

FIG. 15. Type *103-B* microphone boom and type *126-B* microphone boom perambulator.

A new method of determining correct negative and print densities utilizing a modulated high-frequency oscillator has been described by RCA.[13]

The Academy of Motion Picture Arts & Sciences has continued with its program of standardization, and has recommended a number of standards for theater electrical characteristics, dividing networks, filters, and other allied subjects.

(*4*) *Films.*—The Eastman Kodak Company announced a new fine-grain, high-contrast film, designated as *E.K. 1360,* for variable-width recording. It is claimed that white light may be used with this emulsion with results as good as or superior to that obtained with

ultraviolet light and standard positive emulsions. It is also claimed that this film is very quiet in projection and has high resolving power.

The Dupont Film Manufacturing Corporation announced two new sound recording films during 1937, types *214* and *215*, which replace the former *201* and *202* types. The new films retain the desirable

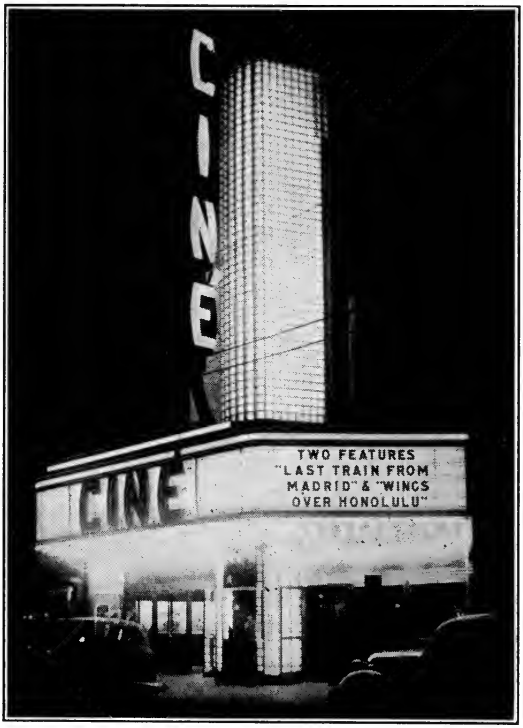

FIG. 16. Glass blocks with lights of various colors behind them.

emulsion characteristics of the former types and differ only in that they are manufactured by a newly perfected technic that eliminates the periodic density fluctuations characteristic of all films manufactured in the conventional manner. This results in a more steady ouput, especially from variable-density films, as is easily observed in the reproduction of constant-frequency films.

(III) SOUND AND PICTURE REPRODUCTION

The past year has been peculiarly barren in the production of new types of sound-picture projection equipment. Many theaters have been modernized with the various equipments described in last year's report. The Academy of Motion Picture Arts & Sciences has labored

FIG. 17. Changeable-letter sign with extended background to allow use of letters of a variety of sizes.

hard to effect standardization of reproducer characteristics and has issued information on the subject during the year.[14]

(*1*) *Motion Picture Theater Lighting.*—In view of the many interesting advances in theater lighting equipment and technic the Committee is including in this report for the first time information on this topic.

Two important developments have occurred during the past year to make it possible to lift the shroud of darkness that has covered

motion picture theater audiences: (*1*) The efforts of the National Carbon Co. to increase the prevailing levels of screen illumination through the use of the newer carbons, thus making possible moderate increases in the general level of the auditorium illumination. This was done by conducting a campaign throughout the industry for greater screen brightness. (*2*) More important still, the widespread use of down lights mounted above the ceiling of the auditorium and projecting a well defined beam of light through a 2-inch hole toward the front of the auditorium. Thus is provided ample general auditorium illumination for patrons to move about and read their programs; and at the same time the decorative colored lighting, which is often of a low order of brightness, as well as the contrasts on the screen, is not destroyed.

Considerable progress has been made also in the use of polished fluted metal reflectors for both decorative and exterior lighting. These reflectors may employ either individual incandescent lamps or neon tubes. They have the effect in many instances of apparently creating many more sources than are actually present.

There has been a more widespread use of the luminous treatment of theater fronts and marquees. These comprise the use of glass blocks as well as luminous panels and polished metal illuminated by projected light. The use of these developments is shown in the photographs of the Cine Theater (Fig. 16). The changeable-letter silhouette sign, previously reported, has been expanded to permit the use of a variety of letter sizes and thus obtain greater emphasis. The illustration showing the Rhodes Theater (*Lost Horizon*) demonstrates this feature (Fig. 17).

Theater interiors are receiving the same general treatment as the outside in that there is more general use of luminous panels and decorated glass blocks, behind which lamps of various colors are placed.

(*2*) *Theater Lighting Equipment.*—For theater use there has recently been made available a 500-watt, 115-volt, *T-14* bulb, biplane-filament, medium-bipost base lamp for elliptical spots and down-lights. This lamp is unusual in that the highly concentrated light-source is placed relatively near the end of the bulb and the lamp is intended for base-up operation. This design results in a minimum of obstruction of the light from the reflector by the lamp bulb.

Two stage-lighting equipment manufacturers have developed a Fresnel-lens spot somewhat similar to those introduced a few years ago for motion picture set lighting. These are to be used for theater

spots and general stage lights. Another equipment manufacturer has placed upon the market an end-seat lighting unit, which consists of a decorated luminous panel to provide aisle illumination.

(*3*) *Accessories.*—About two years ago the Mazda lamp manufacturers introduced a general service lamp having an anti-blackening screen mounted above the filament, upon which the tungsten evaporated from the filament was deposited. During the past year there has been made available a 1000-watt, *T-12* bulb, concentrated-filament projection lamp incorporating a similar anti-blackening screen (Fig. 18). The amount of blackening reaching the bulb is thus reduced to the extent of improving the candle-power maintenance during life 30 per cent over that of a lamp not equipped with this device.

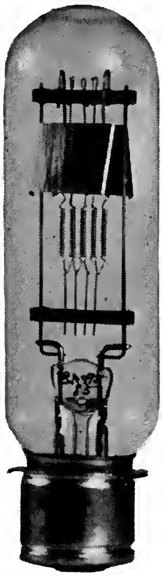

FIG. 18. 1000-watt standard-voltage, *T-12* bulb projection lamp with collector grids.

(IV) PUBLICATIONS AND NEW BOOKS

The growing interest in the use of motion pictures in education was shown by the introduction of a new publication, *Motion Pictures of the World.* This is a quarterly publication issued by International Educational Pictures, Inc., Boston, and is stated to contain a list of all new pictures released in the preceding three months. *World Film News* (Cinema Contact, Ltd., London) made its début during 1937. Current pictures are reviewed, studio activities discussed, progress in the documentary film treated, and television developments noted. It is a pleasure to note that the British Kinematograph Society has been able to replace their *Proceedings* by a *Journal,* of which the first number made its appearance in December, 1937.

Since the last report of the Committee in May, 1937, the following books of noteworthy interest have appeared:

(*1*) Motion Picture Sound Engineering (chapters by various authors), *Academy of Motion Picture Arts & Sciences,* Hollywood, Calif.

(*2*) Sound Recording for Films; W. F. Elliott, *Pitman & Sons,* Ltd., London.

(*3*) Talking Pictures; B. C. Kiesling, *Johnson Publishing Co.,* New York, N. Y.

(*4*) Sound Motion Pictures and Servicing Sound Equipment; J. R. Cameron, *Cameron Publishing Co.,* Woodmont, Conn.

(*5*) Entwicklung der Kinotechnik (Development of Motion Picture Technic); R. Thun, *VDI Verlag*, Berlin.

(*6*) Amateur Movies and How to Make Them; A. Strasser, *Studio, Ltd.*, London.

(*7*) How to Write a Movie; A. L. Gale, *Brick Row Book Shop*, New York, N. Y.

(*8*) Film and School; H. Rand and R. Lewis, *Appleton Century Co.*, New York, N. Y.

(*9*) Motion Pictures in Education; Compiled by E. Dale, F. W. Dunn, C. F. Hoban, Jr., and E. Schneider; *The H. W. Wilson Co.*, New York, N. Y.

(*10*) Camera Lenses and Shutters; R. M. Fanstone, *British Periodicals, Ltd.*, London.

(*11*) Camera Lenses, 2nd Edition; A. Lockett, revised by H. W. Lee, *Pitman Publishing Corp.*, New York, N. Y.

(*12*) Home Movie Gadgets; W. J. Shannon, *Moorfield & Shannon*, Nutley, N. J.

(*13*) Exposing Cine Film; P. C. Smethurst, *Link House Publications, Ltd.*, London.

(*14*) The Secrets of Trick Photography; O. R. Croy, translated by P. C. Smethhurst, *American Photographic Publishing Co.*, Boston, Mass.

(*15*) Film Making from Script to Screen; A. Buchanan, *Faber and Faber, Ltd.*, London.

(*16*) Titeltechnik (Title Technic); F. Lullack, *W. Knapp*, Halle, Germany.

(*17*) Mein Weg mit dem Film (My Experience with the Film); O. Messter, *M. Hess*, Berlin-Schönberg.

(*18*) Technique of Color Photography, 2nd Edition; F. R. Newens, *Blackie & Son, Ltd.*, London.

(*19*) Picturing Miracles of Plant and Animal Life; A. C. Pillsbury, *Lippincott Co.*, Philadelphia, Pa.

(*20*) Photography—Theory and Practice, 2nd English Edition; *Pitman Publishing Co.*, New York, N. Y.

(*21*) Lichtspieltheater, Anlage und Einrichtung (Planning and Equipping a Motion Picture Theater); Bauwelt-Encyclopedia Vol. 9, *Bauwelt-Verlag*, Berlin.

(*22*) We Make the Movies, edited by Nancy Naumberg, *W. W. Norton & Co., Ind.*, New York, N. Y.

Yearbooks were issued by the following publishers:

(*1*) *Quigley Publishing Co.*, New York, N. Y.
(*2*) *Film Daily*, New York, N. Y.
(*3*) *Kinematograph Publications, Ltd.*, London.
(*4*) *Photokino-Verlag*, Berlin.
(*5*) *M. Hess*, Berlin-Schönberg.

Abridgments and collections of original papers were published as follows:

Abridged Scientific Publications of the Kodak Research Laboratories, **17** (1935), *Eastman Kodak Co.*, Rochester, N. Y.

Veröffentlichungen des wissenschaftlichen Zentral-Laboratoriums der Photo-Ateilung Agfa (Publications of the Afga Central Photographic Research Laboratories), *5*, *Hirzel*, Leipzig.

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[1] IVES, C. E., AND CRABTREE, J. I.: "Two New Films for Duplicating Work," **XXIX** (Sept., 1937), No. 3, p. 317.

[2] GRIGNON, L. D.: "Light-Weight Stage Pick-Up Equipment," **XXIX** (Aug., 1937), No. 2, p. 191.

[3] ALBERSHEIM, W. J.: "A Device for Direct Reproduction from Variable-Density Sound Negatives," **XXIX** (Sept., 1937), No. 3, p. 274.

[4] VEITH, L., AND WIEBUSCH, C. F.: "Recent Developments in Hill-and-Dale Recorders," **XXX** (Jan., 1938), No. 1, p. 96.

[5] DIMMICK, G. L.: "The RCA System and Its Application to Various Types of Sound-Track," **XXIX** (Sept., 1937), No. 3, p. 258.

[6] HASBROUCK, H. J., BAKER, J. O., AND BATSEL, C. N.: "Improved Noise-Reduction System for High-Fidelity Recording," **XXIX** (Sept., 1937), No. 3, p. 310.

[7] BATSEL, C. N.: "A Non-Slip Sound Printer," **XXIII** (Aug., 1934), No. 2, p. 100.

[8] *Cf.* ref. *5*.

[9] BAKER, J. O., AND ROBINSON, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions for Optimal Processing," **XXX** (Jan., 1938), No. 1, p. 3.

[10] HOPPER, F. L.: "Power Level Indicators for Sound Recording," **XXIX** (Aug., 1937), No. 2, p. 184.

[11] ALBIN, F. G.: "A Linear Decibel-Scale Volume Indicator," **XXIX** (Nov., 1937), No. 5, 489.

[12] Symposium on Transmission Meters (Spring, 1937, Convention):

LINDSAY, W. W.: "A Transmission Measuring System Utilizing a Graphic Recording Meter," **XXIX** (July, 1937), No. 1, p. 68.

MACLEOD, A. D.: "An Automatic Audio-Frequency Graphic Recorder," **XXIX** (Dec., 1937), No. 6, p. 663.

HILLIARD, J. K., AND SPRAGUE, G. M.: "A Continuous Level Recorder for Routine Studio and Theater Measurements," **XXIX** (Dec., 1937), No. 6, p. 645.

AICHOLTZ, L. A.: "A Curve-Plotting Transmission Meter," **XXIX** (Dec., 1937), No. 6, p. 655.

GRIGNON, L. D.: "A Curve-Plotting Transmission Meter," **XXIX** (Dec., 1937), No. 6, p. 660.

[13] *Cf.* ref. *9*.

[14] "Standard Electric Characteristic for Two-Way Reproducing Systems in Theaters," *Bulletin, Academy of Motion Picture Arts & Sciences*, June 8, 1937; Hollywood, Calif.

APPENDIX A

THE JAPANESE MOTION PICTURE INDUSTRY

The year 1937, while not during its course regarded as an eventful year for the motion picture industry of Japan, will be remembered because it witnessed the enactment of several governmental regula-

tions that will have increasing effect upon the industry during ensuing years. Early in the year Japan found it necessary to overcome her unfavorable balance of trade by an exchange control measure that has steadily become more stringent. Japan's deficiency in natural resources made the application of this measure the more restrictive when the China "Incident" made the purchase of war materials a vital necessity. It was only natural then that certain importations would be classified as nonessential in the face of the national emergency. Unfortunately, motion picture raw film and foreign motion pictures fell into this category. Notwithstanding the fact that certain governmental groups consider Japanese-made motion pictures and newsreels a valuable vehicle for the internal diffusion of propaganda pertaining to the Incident, the supply of imported raw stocks has been cut drastically; in fact, to a point where it is questionable whether the local manufacturers can supply the demand.

As mentioned above, the importation of foreign pictures suffered under these exchange control measures. This fact, however, except for a few newspaper and magazine articles, did not come to the public's attention because foreign distributors began during the autumn to distribute their supplies of previously imported but unreleased pictures. This procedure made possible the distribution of practically the same number of foreign pictures in 1937 as during the previous year, but it certainly did not allow the year to fulfill financially its earlier promises. Approximately 300 foreign pictures were released in Japan during 1937, of which about 25 per cent comprised pictures from European studios. It will be noticed that European productions seem to be steadily gaining ground against American pictures, but this does not necessarily imply they are gaining popularity. Pictures produced under the social and political restraint peculiar to European countries are much more likely to find favor in the eyes of the Japanese censors, especially in view of governmental amity. Also it must be borne in mind that the exhibitor is able to make more favorable terms for these pictures than for the American pictures. The average American picture, however, is still the better box-office success, especially in the large city theaters that make a specialty of showing foreign films.

It is estimated that in 1937 about 600 Japanese-made pictures of the entertainment type were released. This includes features, comedies, and shorts. There is still an appreciable number of silent pic-

tures made expressly for the small country theaters not equipped for sound. Incidentally, these theaters still employ the *benshi* (narrator) to explain the action of the picture to the audience. These unscored pictures average only about 5 or 6 prints per picture as compared to the 10 to 12 prints made for each sound picture. On the basis of released footage there were better than 4 feet of sound-film released to every foot of silent film. The writer believes the total released footage approximated 50 million feet in 1937. About 50 per cent of the productions are still of the historical type. A possible reason for the sustained popularity of these classical plays is the fact that foreign releases provide the modern style picture on a scale upon which it is difficult for the local producers to compete.

There was considerable activity in the production of documentary and educational films. Governmental agencies, newspapers, universities, and cultural societies as well as the motion picture companies participated in making some 250 such pictures. Since, however, these films were made primarily for private distribution, figures as to the lengths and subjects are difficult to obtain. The following classifications, however, will cover probably 80 per cent of these films: tourist, industrial, propaganda, educational, sport, and military.

The China Incident introduced into Japan an unprecedented interest in news films. Almost overnight newsreel theaters sprang into existence in the large cities. These theaters are small, accommodating only 200 or 300 persons and offer a 1 to $1^1/_2$-hour program made up primarily of newsreels with one or two shorts. News of the Incident monopolizes the screen to such an extent that at this early date when the spectacular Chinese news is diminishing in volume consternation is already arising as to just what to do with many of these theaters after the Incident is closed.

The construction of many new theaters was completed last year. Two large first-class theaters, one in Tokyo (the *Kokusai Gekijo*) and one in Osaka (the *Umeda Gekijo*) were built by the Shochiku interests and Toho interests, respectively. Both theaters are equipped with Western Electric sound reproducing equipment. The *Kokusai Gekijo* is without doubt the largest theater in Japan and perhaps one of the largest in the world. It has a total seating capacity of about 3000. The new theaters are being built with the proper acoustical considerations incorporated in the design and construction materials, a matter that previously had been given little thought.

At this point it may be interesting to point out a few pertinent facts about theaters and attendance. In point of view of attendance, last year set a record, with a figure approaching 300,000,000 paid admissions. There are about 1400 theaters in Japan, 1100 of which show Japanese films exclusively, the remainder having mixed or all-foreign programs. Needless to say, the latter group are concentrated in the large cities. About 85 per cent of the theaters are equipped for sound, but only the larger theaters have invested in imported equipment; Western Electric leads with more than 130 theater installations. It can be seen from the above figures that by far the major portion of the sound reproducing equipments is manufactured locally.

Several of the studios in Japan are equipped to process their own films by machines: notably, J. O. Studio Co., P.C.L., Shochiku (Tokyo) and Nikkatsu (Tokyo). There are also several companies that make a business of processing film, *i. e.*, local negatives and positive as well as duplicates of foreign productions. Of these the largest is the Far East Laboratory, with eight positive and four negative machines of the Debrie type. Others in this field are J. O. Studio Co., P.C.L., K. S. Talkie, and Yokohama Cinema. The latter two employ machines of the Art Reeves type, and process largely Japanese newsreels. The majority of these machines have positive processing speeds of 20 to 40 feet per minute and a negative processing speed of 5 to 10 feet per minute. For financial reasons, however, many studios are still processing their negative and positive films by the rack-and-tank systems, though at present that is true only of those interested in the production of silent pictures.

The motion picture laboratories in Japan have, in the past few years, become conscious of the advantages to be gained from close sensitometric control of their processing. This is especially true of the laboratories employing machines, where the processing of sound negative has made development control a vital necessity. The Eastman type II*b* sensitometer has been universally accepted as the standard instrument for this control work.

The Fuji Photo Film Company has expanded its manufacturing facilities in an effort to supply the raw film necessary for the local market, now that imported stocks are so severely restricted. Their products include a clear base panchromatic negative film, a positive film and a newly introduced sound recording film.

APPENDIX B

PROGRESS IN GERMANY

As a result of experience with the magnetic oscillograph introduced four years ago for variable-width recording, this system has now been

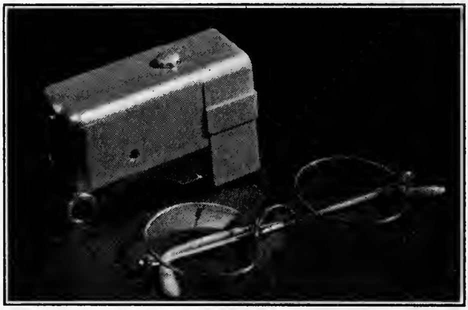


FIG. 19. Minicord modulator.

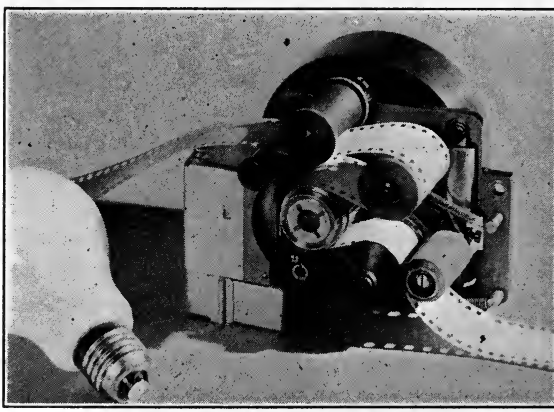


FIG. 20. Minicord sound mechanism.

developed in very small dimensions. Including the optics the oscillograph measures only 3 × 4.5 × 8 cm.; the weight is approximately 200 grams; the power consumption of the lamp is 3.5 watts; 5 milliamperes are required to operate the mirror. Fig. 19 illustrates

the recorder known as the "Minicord" sound recorder. Variable-width recording may be done with this instrument without lowering the noise level. The amplifier and other electrical equipment have been reduced to a minimum of weight and space. The amplifier and batteries of 10-hour capacity are built into a case measuring 450 × 130 × 390 cm. and weighing 15 kg. Fig. 20 shows the 35-mm. sound mechanism in comparison with a 60-watt lamp. The results attained with this apparatus may be regarded as very satisfactory. The small size of the apparatus makes its use possible not only in combination with standard film cameras forming a single unit, but also in combination with substandard film cameras.

In the field of reproduction the new sound apparatus for very large theaters, made by the Klangfilm Gesellschaft and called "Euronor," is remarkable, especially for its very large compound loud speaker. The size of the latter is determined primarily by the labyrinth system which consists of a large membrane 50 cm. in diameter, a horn having a length of 2.6 meters, and an opening of 4 square-meters. The efficiency of this labyrinth system and its capacity are so great that about 12 watts of undistorted output may be obtained at 50 Hertz. Four upper cones 1.6 meters in length are provided for the medium and higher frequencies. Fig. 21 shows the loud speaker.

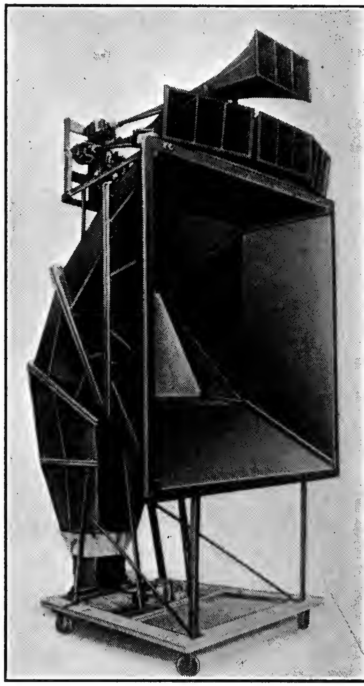


FIG. 21. Klangfilm loud speaker system.

Experience with this apparatus has proved that the extension of the frequency range at the lower end represents a considerable step toward more natural reproduction. The possibility of reproducing special effects (explosions, earthquakes, *etc.*) is, of course, considerably greater due to the high acoustical efficiency at the low frequencies.

APPENDIX C

GENERAL FIELD OF PROGRESS OF THE MOTION PICTURE INDUSTRY IN GREAT BRITAIN *

Although there has been considerable improvement in the technical and artistic standards of British pictures, the year 1937 has been an unsatisfactory one for the industry. Financial interests showed a desire for severe retrenchment largely owing to disappointing returns from the 1936 program and there was a rapid falling off in the number of pictures in active production.

Another reason for the decline has been the general uncertainty as to the final results of the Government's new Films Bill, designed to replace the expiring Act of 1927. The main object of the bill is, of course, to foster the production of British films, and the Government, starting with the Moyne Report as a basis, has considered the views of all sections of the industry. Unfortunately a fundamental conflict of interests has been revealed and the bill will require considerable modification before a compromise can be reached.

An important function of new legislation, and one that is generally agreed to be desirable, would be not only to regulate the proportion of British films exhibited but also to set a minimum standard of entertainment quality and so eliminate the damage to prestige caused by "quota quickies," a type of picture made more with the object of complying with the law than as entertainment. The means of achieving this quality standard is still under discussion but it seems likely that a minimum cost figure will be established with the provision that a fixed proportion will be spent on labor.

With the American product available as a standard of comparison no act can guarantee that competitive films are produced, but it is felt that the studio facilities available in this country are ample and that if a reasonable compromise bill can be passed and future conditions stabilized a return of confidence will produce increased activity in the coming year.

Studios.—Amalgamated Studios, Elstree, were completed in the early part of this year. These studios comprise four large stages, each equipped with its own dressing rooms, cutting theater, and sound

* Received June 21, 1938, from R. J. Engler.

recording and monitoring facilities. Two large theaters are available for the combined purposes of dubbing, scoring, and reviewing. The sound equipment is Western Electric. Owing to the depressed state of the industry the studios have not yet started production.

The Warner Brothers Studios at Teddington have been equipped with RCA variable-width recording facilities, which are to be converted for class *A* push-pull operation in the near future.

In order to eliminate price-cutting, an agreement was reached between the major service studios on standardizing charges to producers, and during the year various means, such as the making of pictures on a coöperative basis, have been tried to keep the studios in production.

Laboratories.—Generally the laboratories have had a quiet year, although improvements in technic have occurred in some instances, particularly in the use of sensitometric methods of development control and an increased use of turbulation of the developing solutions. Efforts to improve the quality of duplicates have led to the use of two new film products, Eastman fine-grain duplicating positive and Eastman fine-grain duplicating negative, both extensively used in the U.S.A. These new films differ materially from the normal duplicating product, and require considerable modification of the printing equipment set aside for this work. A certain amount of tinting and toning of release prints was undertaken although the quantity of this kind of work does not seem to be increasing. Several laboratories are adding 35-mm. to 16-mm. sound and picture reduction printers, and there was an increase in the use of 16-mm. prints, mainly for industrial purposes.

The new Technicolor Laboratories at Harmondsworth started commercial operations early in 1937. By the end of the year they were working at full single-shift capacity and were manufacturing all British release print requirements as well as a number of foreign-language versions of all current Technicolor pictures produced in England and the United States.

Denham Laboratories, situated near London Film Production Studios, are now in operation and are equipped with the latest type of processing apparatus. Five DeBrie daylight developers are available with seven DeBrie Duplex printers, one Bell & Howell type printer as well as an optical printer for special effects. A 35-mm. to 16-mm. optical reduction printer is also installed.

Twelve non-slip sound printers are now installed in London Labo-

ratories and are proving valuable for re-recording copies and duplicating work.

Newsreels.—The major event in the newsreel sphere was the recording of the coronation ceremony, particularly as permission was obtained from the authorities to take photographs within Westminster Abbey. The conditions were, however, very difficult and the results obtained, which included several colored versions, must be regarded as remarkably successful.

British Movietonews have moved to enlarged premises in Soho Square and Kay Film Laboratories have established a plant adjacent so as to give an improved service.

Technical Advance.—Messrs. W. Vinten, Ltd., have developed a step-wedge printing machine for making rising density test print strips of negatives and also density strips for taking the speed or exhaustion of developing baths. This machine prints eleven frames with one pull of a handle, and can be operated in daylight. A synchronous generator ensures steadiness of the voltage on the light-source from day to day and a special photocell is used to check the color constancy of the lamp.

The same firm has also produced a complete portable daylight processing unit which can be mounted, complete with air-conditioning, in a moderately sized lorry. A camera taking 250 pictures a second and equipped with a special view-finder has also been developed to supplement the existing high-speed type. This camera is equipped with a 400-ft. magazine and is very light in weight.

A new type of multiple printer is being developed capable of taking four 16-mm. prints from one negative at the same time. It is provided with four double-8-mm. heads interchangeable with the 16-mm heads. The machine can also be arranged to use four negatives and take four positives when a special light control is provided for with separate control of each of the four printing lights.

A 35-mm. to 16-mm. sound reduction printer is available operating on a dual track method with a unique system of mechanical synchronization between 35-mm. and 16-mm. films.

Exhibition.—Despite the decline in the production side of the industry 1937 was an improved year for exhibitors. Extensive new building continues, although a campaign against overbuilding has been started and attempts made to include provisions against it in the New Films Bill. There has, however, been a halt in the building of news theaters and it is felt that the trade will eventually

regulate new building in coöperation with the renters by refusing to supply films to unrecognized cinemas.

Technical developments have been in the direction of the increased use of two-way horn systems with multicellular high-frequency units, the Western Electric Mirrophonic system having been demonstrated early in the year.

Broadcasting and Television.—The broadcasting of advertising programs intended for British listeners from certain continental stations continues despite proposed international legislation to limit it. The programs are generally recorded either on disks or by means of the Philips-Miller system.

Television has made some progress in the home entertainment field and several successful outside broadcasts have been made, notably those of the coronation ceremony and several from film studios. The Gaumont British and British Movietonews reels continue to be a regular part of the programs.

As yet, however, the number of sets is estimated as only 2000, so that no effect is likely to be felt by the cinemas for a considerable time. Factors limiting a substantial increase in these numbers are the limit of coverage of the London area, the restricted hours of transmission, and the high cost of receiving sets.

However, recent demonstrations of large-screen television by the Scophony and Baird systems have proved encouraging and its use in cinemas is being considered. Both the companies demonstrating are associated with large theater circuits so that the systems will probably be exploited as soon as technical development is sufficiently advanced. The future of television in motion picture theaters will depend upon several factors that are at present doubtful. Among these are the questions of the copyright of the B.B.C. television transmission and the possibility of providing programs, suitable for showing in cinemas, either by the B.B.C. or some separate organization. The latter would, of course, entail the erection of special radio transmitting stations or the provision of suitable cable distribution networks.

THE MULTIPLANE CAMERA CRANE FOR ANIMATION PHOTOGRAPHY*

W. E. GARITY AND W. C. McFADDEN**

Summary.—*In connection with the general improvement in cartoon technic, it was recognized that several developments could be undertaken that would add much, if successfully adapted, to the power and charm of animated motion pictures. By confining cartoon photography to a single plane in front of the camera, the expense and difficulty of creating a convincing illusion of depth and a real-life appearance by camera movement made the consideration of a multiplane technic imperative. The out-of-focus diffusion and the differential movement of foreground and background of scenes can be achieved most easily by separating the elements on different planes in front of the camera. The problem resolved itself into the adaptation of glass-shot technic to cartoon production. In separating the scene elements into several planes, many other advantages were gained, such as lighting control of single-scene elements, ease of using special effects equipment, and possibility of using backlight and process backgrounds.*

The answer to the problem was the multiplane camera, built with the view of accuracy of control, complete flexibility of scene set-up, and ease of operation. This required plane elements that could be quickly and accurately assembled and disassembled; separate lights for each plane; a quick-reading and accurate indicating system; and an interlocked system of controls.

Because the light level on each plane is an important part of every set-up, a special light-measuring system had to be devised. The number of machine adjustments involved was so large that a master control sheet was laid out, giving complete operation information for each frame of film. As a final check before exposure, a periscope type of finder was devised so that the chief operator could check the set-up visually before each exposure. To write out the master control sheets, it was necessary to develop a scene-planning group of artists and technicians to control and plan the use of the machine in creating the desired illusions.

The results in enhancing the effectiveness of animated motion pictures have been very satisfactory. The multiplane technic has proved so flexible that its complete possibilities will be realized only with experience.

The usual cartoon technic is to photograph both character and background on one plane in sharp focus. The multiplane technic is

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 14, 1938.

** Walt Disney Productions, Inc., Hollywood, Calif.

the separation of scenes into their several foreground and background elements, and designing them to be photographed at different distances in front of the camera. The camera photographs through these elements, which are painted on glass. On one or more of the elements the usual animated characters are held in register to the action level part of the scene.

The advantages of using a multiple-plane technic in cartoon photography are manifold. An evaluation of these advantages, an analysis of the means of getting them, and the adaptation of these means into the established technic of animation, comprised the background for the design of the multiplane crane.

The primary problem leading to the multiplane idea was to increase the illusion of depth in animated motion pictures. To do this, there are several things, short of true stereoscopic photography, that can be done. Careful handling of color and painting technic will add much to the illusion of depth. However, the artistic problem of getting and controlling the out-of-focus diffusion of foreground and background scene elements is very difficult when whole scenes are shot on one plane in sharp focus. Controlling this diffusion by using several plane scenes and adjusting the depth of focus as desired gives a more convincing result. But the most important part of the appearance of depth comes from camera movements.

Pan shots, in cartoon parlance, refer to scenes in which the camera appears to travel parallel to the background. It is in pan shots that the real-life movement between foreground and background elements can best be portrayed. As the scene elements are moved rather than the camera in photographing the cartoon, the speed of the elements can be controlled as they pass in front of the camera. In the pan shot, therefore, the sky, the middle distance, and the foreground can be separated and moved at speeds that will maintain the correct perspective relations of the scene as originally conceived by the artists. While it might seem possible to paint all the elements on separate transparencies to be shot on one plane and still control the perspective by different movements, it is not practicable because the pile-up of transparencies will cause noticeable shadows of the top characters upon the bottom characters if the pile-up is more than 0.040 inch thick.

In a so-called truck shot, in which the camera appears to move toward or away from an object, a depth effect can be accomplished only by the use of a multiplane scene. In moving the camera along

the lens axis, it is easily shown that the photographed fields nearest the camera are changed in size at a proportionally greater rate than those farther away. The proportional change varies inversely with the field size, which is exactly the condition found in real-life observation. In multiplane scenes, it is possible to keep the very distant background and sky elements from changing in size during camera trucks by keeping them at the same distance from the camera while the latter is moving with respect to the characters and foreground.

Overall light changes showing transitions, such as dawn to full daylight in the same scene, can be done in cartoon work with fades or filters. But when only part of the scene requires a lighting change, in standard cartoon photography such a change can be done only by double exposures. In multiplane photography, the lighting changes can be achieved easily by filtering or otherwise controlling the light on the element to be changed. A large range of light level can be attained by using bulbs of different wattages in the lamp-boxes. For smaller variations in light, a range of voltage from normal to 20 volts above normal can be used. This over-voltage range is necessarily small because of the usual limitation due to variation of the color of tungsten lamps with voltage. In practice it has been found that this voltage range is consistent with reasonable bulb life and color quality. At times the color variation of tungsten lamps is used to advantage by running them under voltage for certain effects.

Because of the separation of scene elements, the possibilities of special effects are greatly increased. Distortion and diffusion glasses for a single background element can be used without affecting the rest of the scene or characters. The use of mirrors and other optical equipment is greatly facilitated in multiplane scenes. By careful planning, almost any scene can be broken down in such a way that control of lighting, color, and optics is achieved over any part or all of the scene. This control would not be at all practicable if the technic were confined to a single plane. While animation effects are apparently unlimited, there are certain weaknesses that special-effects equipment circumvents. It is impracticable to paint gradual changes of light level or color, or to animate the slow distortion of backgrounds or reflections.

As the multiplane idea necessitated transparent backing for cartoon characters, the door was opened to a large range of effects with back-lighting such as the glow around lamps, sparkles, sunsets

through dark clouds, *etc.* Although process backgrounds have not been used, they are quite possible with the multiplane crane.

From the experimental work on the multiplane idea, the necessary requirements for a successful camera crane were set up (Fig. 1). Two general types of supports for the scene elements were required.

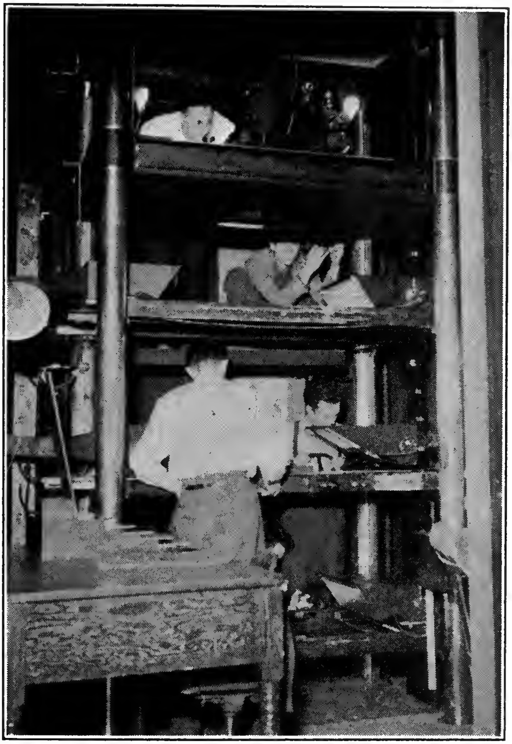


FIG. 1. General view of multiplane crane.

One was the contact plane, which would handle both glass backgrounds and animation; and the other was the background plane, which would support only the glass backgrounds. However, the desire for freedom from limitations in breaking down scenes made it imperative that it be possible to arrange the various planes in front of the camera in any order. That meant that the planes would have to be quickly and easily demountable from the structure and light enough in weight to be handled easily. It meant that each plane

would have to carry its own light-boxes. Because of the large number of background separations desired, the overall height of the plane and light-boxes had to be kept to a minimum: it was possible to keep it under 14 inches. The contact planes had to carry all the

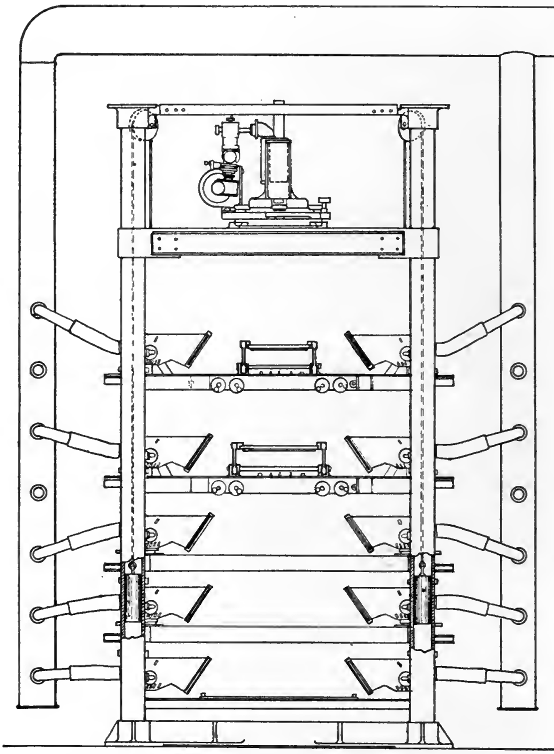


FIG. 2. Multiplane camera, front elevation.

usual cartoon facilities for handling animation, such as peg bars, platen, *etc.*, in addition to the background support.

The desire for controlling depth of focus over a large range made many revisions necessary in the usual cartoon camera set-up. Analysis of lenses of various focal lengths, focusing close to the camera, showed that the depth of focus was practically independent of focal length for the same photographed field size. It remained for us to choose a lens with an angle that would give us a convenient range of field sizes within the limits of our structure. For a large enough

depth of focus, it was necessary to stop the lens down as small as $f/32$. In making three-color separation negatives, the small lens aperture raised the light requirements far in excess of those of the usual cartoon system. As we use stop-motion photography to make the successive color separations, we were able to reduce the light to about 500 foot-candles by increasing the exposure time. We established, for our purposes, exposure times varying from 0.9 to 9 seconds per exposure.

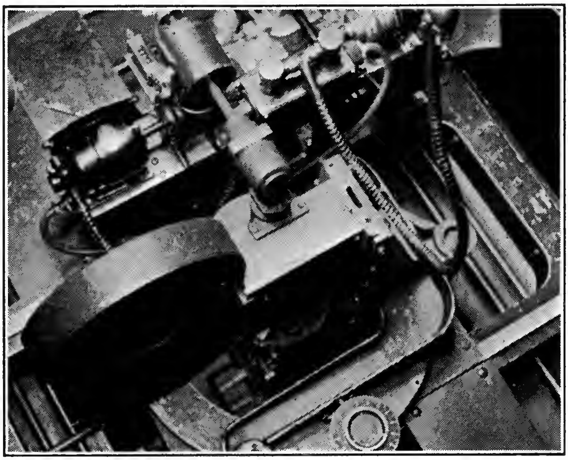


FIG. 3. Top view of camera carriage showing camera drive and "East-West, North-South" and rotational mounts.

In mounting the camera, the usual small horizontal movements in two directions as well as the vertical movement were required. A rotational movement about the lens axis was also required for angle shots and airplane spin effects, *etc.* By a combination of horizontal and rotational movements, any type of angular or rotational move was possible. It was found necessary to equip each of the planes with a vertical truck movement, so that the photographed size of any scene element could be controlled individually.

In lighting the photographed field, it was found feasible to paint for the effect desired and to use as flat a light as possible. However, provision was made for filters and special-effects masks over each light-box. The one most difficult problem was spill light. It was finally necessary to develop special light-boxes that would simul-

taneously light the field flatly, have a high efficiency, keep spill light off the planes immediately above and below, and have an overall height limited to 10 inches. Heat from high-intensity light was serious and necessitated an exhaust system for all light-boxes (Fig. 2).

Because the operation of the machine was to be such that it could be tied into regular production, a planning group of technicians and artists had to be developed to prepare the necessary camera instructions.

To minimize operation errors, an interlocked control system had to be developed that would keep the numerous machine adjustments coördinated. The regular cartoon system of scene set-up and exposure sheets had to be expanded to include the new elements and movements of the multiplane crane.

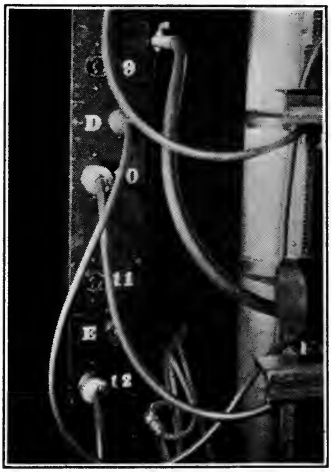


Fig. 4. Service gutter for power feed to planes.

The crane itself is a vertical four-post structure to which the various planes are movably attached. The four posts are rigidly held in rectangular top and base castings 40 × 60 inches in size. The posts are unsupported except at the ends, and are ground steel tubes $4^7/_8$ inches outside diameter, with $^1/_4$-inch walls, and are 11 feet 4 inches long. Each tube has a gear rack bolted on along its entire length. The rack teeth are matched so as to provide very accurate control of the height. In the control system, the optical axis and the floor form the origin. The rack teeth are numbered in inches, reading from the floor, to serve as height indicator for all equipment on the crane. The tubes are the guides and the gear racks are the supports for all the equipment. As can be seen from the general view of the crane (Fig. 1), the camera is at the top and photographs vertically down through the various planes.

The camera carriage is a rigid platform guided by bushings and supported by worm-driven rack gears (Fig. 3). The carriage is counterweighted at each corner by weights hanging inside the tubes. On the camera carriage is an "east-west" dovetail slider which carries a "north-south" dovetail slider. On the north-south slider is a large

ball-bearing ring which supports the camera and drive and allows them to rotate through an arc of 360 degrees. The camera is mounted so that the optical axis coincides with the center of rotation of the mount. Every movement has calibrations correlated to the production technic so that camera movements can be laid out and calculated, prior to photographing, with a high degree of accuracy, and, by the same means, any given set of conditions may be repeated at any time. Due to the requirement of variable exposure time, the camera is driven by a synchronous motor through a variable-speed transmission and stop-motion clutch. A selsyn motor is also

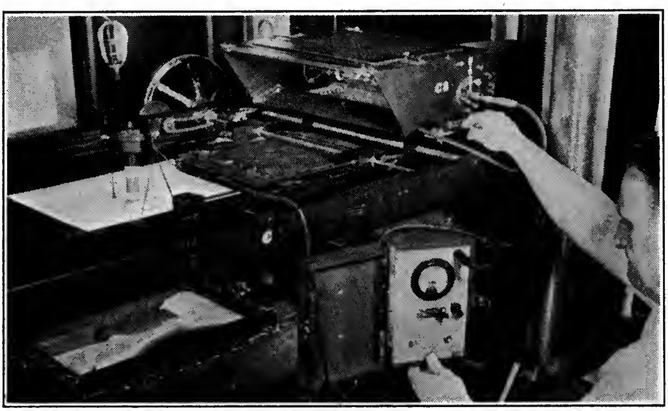
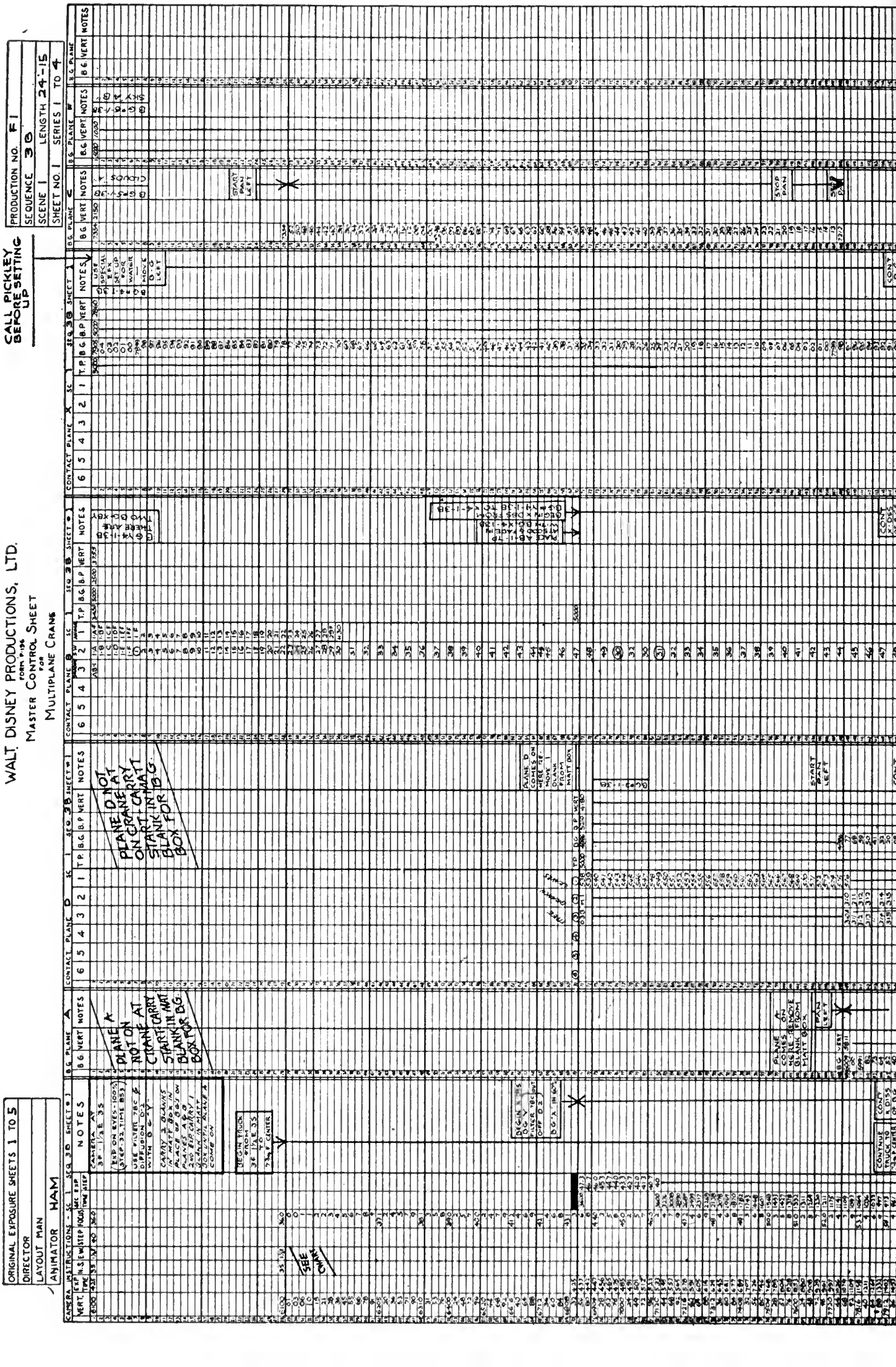


FIG. 5. Adjusting reflectors with the special photometer.

tied into the stop-motion shaft to drive the operation control mechanism and film counter.

The most complicated of the scene element supports are the action levels or contact planes. The contact planes contain all the features of a standard cartoon photographing table, plus the background support. The plane carries its own light-boxes. The power control circuits and compressed air are fed to the planes from a special gutter having a series of plugs and valves arranged along its length (Fig. 4). This gutter is mounted vertically and parallel to the rear left post of the crane. The background planes are fitted to carry transparent backgrounds of various widths in a movable east-west slide, each carrying its own light-boxes and control circuits. All the movements are fitted with calibrations referred to the optical axis as center, so that all planes have indications that are mutually


WALT DISNEY PRODUCTIONS, LTD.
FORM P-136
MASTER CONTROL SHEET FOR MULTIPLANE CRANE
CALL PICKLEY BEFORE SETTING UP
PRODUCTION NO. F1
SEQUENCE 38
SCENE 1 LENGTH 24-15
SHEET NO. 1 SERIES 1 TO 4
ORIGINAL EXPOSURE SHEETS 1 TO 5
DIRECTOR
LAYOUT MAN
ANIMATOR HAM
PLANE A NOT ON AT CRANE START CARRY BLANK IN MAT BOX FOR B.G.
PLANE D NOT ON CRANE AT START CARRY BLANK IN MATT BOX FOR B.G.

consistent. All planes are fitted with rack gear vertical supports and movements similar to those of the camera carriage.

The lamp-boxes are of the adjustable facet reflector type, designed to fit a multitude of stringent conditions (Fig. 5). The reflectors are individually adjusted with the use of a caesium cell photometer designed especially for the purpose. The adjustments control flatness of the lighting as well as the intensity of illumination.

Due to the fact that in the normal operation of this camera the services of one to six operators may be required, and their efforts must all be coördinated and the possibility of human error eliminated, all the indices have been provided with special illuminating lamps. While the operator of one plane is preparing his various controls for photography, these lamps permit him to read the indices. When he has set all the controls, he pushes a button, conveniently located on his particular plane, which turns out these lights, making it impossible for him to read his control setting. When he pushes the button he trips a specially designed relay which cuts out the illumination of his indices and places the electrical circuit in such condition that when all the planes have thus functioned, then and only then, can the chief operator trip the camera. These relays are connected by a series method so that all the relays from the various planes in operation must be closed before the chief operator can energize the electrical mechanism that trips the camera. When the exposure is completed to the chief operator's satisfaction, he pushes a button that releases all the planes simultaneously so that the individual operators may proceed with establishing the settings for the next exposure.

To correlate the detailed manipulation, it was found necessary to produce a master control sheet showing on it the settings of each plane for each successive operation. This master control sheet is made out in duplicate. The duplicate sheet is split up and the portion carrying the camera carriage instruction is given to the camera operator; the portion carrying the instruction covering plane *A* is given to the operator of plane *A;* and so on; and the original master is placed on a master control board immediately in front of the chief operator (Fig. 6).

To eliminate errors on the part of the chief operator in knowing at just what frame he is working, a selsyn interlocked motor has been incorporated in the camera mechanism. A second selsyn motor is incorporated in the master control board and operates a glass ruler device that indicates to the chief operator exactly upon which frame

he is working. In other words, when a new control sheet is placed on the board, the glass ruler is returned to the first exposure, the interlocking motors are energized and the master ruler driven by the camera, regardless of whether the camera moves forward or backward. There is therefore no opportunity, except in the case of electrical failure, for the chief operator to make an error.

In view of the fact that projection type lamps are used, and for the technicolor process it is required that they operate a voltage higher than rated, their lives are necessarily short. To circumvent this condition, an electrical circuit has been arranged to introduce a resistance into the main current supply line so as to reduce the voltage on the lamps to about 85 or 90 volts during the time when changes and camera set-ups are being made. A special relay is provided in the circuit so that it is impossible for the chief operator to make an exposure while the protective resistance is in circuit.

To increase the life of the bulbs further, as well as to reduce the heat in the camera area, it was necessary to incorporate an exhaust system in the lamp-boxes (Fig. 2). This equipment was designed to provide one change of air per second in the lamp-box, and has been quite successful in increasing the useful life of the lamp besides preventing practically all heat conduction through the lamp-box.

In the development and design of the light-sources used with the camera, it was necessary to develop special photometric equipment due to the acute angle of the light-source to the photographed area. which averages about 27 degrees. None of the commercial photometric devices was satisfactory. The device developed for this particular function contained a caesium photoelectric cell in a vacuum-tube voltmeter circuit (Fig. 5). The photocell was mounted so that its cathode scanned a small disk of heavy ground-glass suspended about 5 inches below the photocell. This glass disk is held in position by means of a piece of glass tubing about 2 inches long, the disk being centered at the bottom of the tube. The glass tube is suspended in a piece of brass tubing about 3 inches long, and the interior of the brass tube is entirely opaqued and rendered non-reflecting.

The photocell and tube are suspended by means of a double trunnion of a design similar to that used to suspend a ship's compass. The outer pair of trunnions is established in a ring, and in the ring are set three posts so that the ground-glass disk is suspended about $^1/_4$ inch above the illuminated surface to be measured, and the three supporting legs are positioned so as not to cast a shadow upon the

ground-glass disk. The instrument measures very accurately the perpendicular light, which is the useful photographic light. A device of this type is necessary so that the reflection surface remain absolutely parallel at all times; a slight deviation from the level would cause a wide discrepancy in our measurements. This apparatus is useful only in leveling the overall illumination, and is impracticable for establishing the light levels for the photography.

The scene-planning group of artists and technicians was developed to control the use of the multiplane crane in creating the desired illusions. In breaking down a scene the group works with a pencil

FIG. 7. Multiplane set-up on crane showing four levels, with water and reflections.

perspective layout of the scene as originally conceived by the layout department. After due allowance has been made for any special set-up for some particular effect, the scene is broken into its foreground, action, and background elements and these elements are indicated on the original layout (Fig. 7). As the original layout is already drawn to action-level size, every change in size for the separations is referred to the action level as a base. Field sizes are then chosen for each of the separated backgrounds and the separations are photostatically enlarged or reduced, depending upon their positions above or below the action level. In order to get correct perspective speeds in pan shots, the real-life distance from the action level to each separation is estimated by measuring the drawn size of similar objects in the original layout. The speed of motion for any

plane is the contact-level speed multiplied by the ratio of the separation-field size to the contact-level field size; and by the ratio of the drawn size of an object, in the original layout at the real-life distance of the separation to the drawn size of the same object at the real-life distance of the contact level.

To control the out-of-focus diffusion, a depth-of-focus chart is used. After a circle of confusion for a particular separation is chosen, and using the lens aperture that will give enough depth of focus, the field size of the separation can be set by using the distance from the focal plane or contact level that will have the diffusion desired. In making finished backgrounds, photostats are traced upon the transparency to indicate to the artists the size and composition. Then specially trained artists paint the elements. The artist must develop a high degree of skill to handle the color harmony from plane to plane in such a way that the planned effect of depth will be maintained.

To lay out the master control sheets, the technicians keep records of all the decisions, as to the effects desired, upon a multiplane scene script. When the scene is completed for photography, it is checked for both artistry and mechanics, and then the master control sheets are laid out by the technicians who give the complete operating instructions for each frame of film.

The multiplane technic was first used and developed on the "Silly Symphony" entitled *The Old Mill* and was used extensively in the feature production *Snow White and the Seven Dwarfs*. Following the latter, the Silly Symphony *Wynken, Blynken and Nod* was produced in which the multiplane technic was also employed. The technic has definitely improved the photographic quality of the product and we are convinced that its possibilities are unlimited and that the results justify the increased cost of operation.

DISTORTION IN SOUND REPRODUCTION FROM PHONOGRAPH RECORDS*

J. A. PIERCE AND F. V. HUNT**

Summary.—*When the spherical tip of an ideal reproducer stylus slides over a warped groove surface having a sinusoidal profile, the traced curve is not exactly sinusoidal. An analysis of the harmonic content of the traced curve, similar to that given by DiToro (J. Soc. Mot. Pict. Eng., Nov., 1937) but avoiding his approximations, is directly applicable to reproduction from vertical-cut records. These results may be applied to reproduction from lateral-cut records by taking the original groove surface as inclined approximately 45 degrees from the horizontal, projecting the traced curve upon the horizontal and vertical planes, and adding in proper phase the guidance of the stylus tip by both sidewalls. It is shown that there is a residual vertical component of stylus motion ("pinch" effect) and complete cancellation of all even harmonics in the tracing distortion. Computation of the remaining odd harmonics indicates that, when the ideal lateral-cut reproducer characteristics include ideal "following" for vertical motion at signal frequency, a lateral-cut record may be reproduced with one-fourth to one-tenth the rms. distortion of a similarly recorded vertical-cut record. These results are displayed for convenient reference by contours of constant distortion upon a universal chart, the dimensionless coördinates of which characterize any recording condition and allow immediate specification of the maximum permissible recorded amplitude, maximum predistortion of the frequency characteristic, and the required clearance angle of the recording stylus.*

In the complicated process of recording and reproducing a phonograph record there are many ways in which non-linear or harmonic distortion may enter the system. If one assumes that the electromechanical conversion is perfect in both recording and reproduction there still remain two geometric factors introducing harmonic distortion which may not be reduced except by altering the dimensions of the apparatus. The first of these is "tracking error," and may be defined as the angle between the vertical plane containing the vibration axis of the mechanical system of the reproducer and a vertical plane containing the tangent to the record groove. Such an angle arises from the convenient mechanical device of pivoting the reproducer tone-arm from a fixed point. If the vibration axis of the

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reproducer, extended, passes through the tone-arm pivot, it may readily be shown that the vibration axis can never be truly tangent to the record groove at more than one value of the radius. On the other hand, if the vibration axis of the reproducer system is set at an appropriate angle with the line connecting the stylus tip and the tone-arm pivot, and if the length of the tone-arm is properly adjusted to the distance between the tone-arm pivot and the record axis, then the tracking error may be held to a few degrees. In the case of reproduction of vertical-cut records this tracking error does not introduce distortion and the tone-arm may therefore be made quite short. On the other hand, in the reproduction of lateral-cut records a sinusoidal groove is not traced sinusoidally by the reproducer stylus tip if the tracking error is considerable. Olney[1] has discussed this effect and has given numerical examples of the harmonic distortion introduced under practical recording conditions. He shows, for example, that even with so large a tracking error as 15 degrees (as large as is usually met in practice) the maximum distortion to be expected from this source is approximately 4 per cent. On the other hand, it is readily possible to offset the vibration axis in such a manner that the tracking error does not exceed ± 6 degrees, and under these conditions the harmonic distortion introduced by tracking error can be neglected in comparison with other distortions met with in a practical recording system.

A very much more serious source of harmonic distortion arises from the fact that the tip of the reproducer stylus has finite size. The curve traced by the center of the tip (which we shall assume to be spherical) of a reproducer stylus sliding over a sinusoidal groove surface is not, unfortunately, sinusoidal, and it is embarrassing that the only way to reduce the distortion due to this effect is to reduce the size of the needle tip. Such reduction can be carried only so far, with the practical result that this distortion, herein called *tracing distortion*, currently remains the most serious limitation in the attainable fidelity of phonograph reproduction. DiToro[2] has discussed this type of distortion with an analysis based upon an approximate sine curve composed of parabolic and straight-line sections, and has given results that are applicable to reproduction from vertical-cut records. These results are satisfactory for high values of distortion, but are in some error at the lower and more interesting values. It is the purpose of this paper to present an extension of this work, based upon a method of computation that avoids DiToro's approxi-

mations, and to apply the results to an evaluation of the tracing distortion arising in the reproduction of both vertical and lateral-cut records.

HARMONIC ANALYSIS OF THE TRACED CURVE

The first step in the solution of this problem lies in the harmonic analysis of the curve traced by the center of a circle that slides or rolls along a sine curve. These results will give directly the components of motion of a spherical needle tip tracing a vertically modulated record groove, and the application of the results to the analogous motion of a needle tip tracing a laterally modulated groove will be discussed later. Fig. 1 represents such a circle sliding along a cosine curve. It will be noted that the traced curve (shown dotted) is not mathematically simple. It is, however, so simple physically that it seems as though it should be numbered among the curves that are dignified by titles, and for want of a better name we have dubbed this curve the *poid* and shall so designate it in this discussion.

The coördinates of the center of the tracing circle, ξ, η (which are the coördinates of a point on the poid), may be expressed in terms of the corresponding coördinates of the point of contact of the circle with the cosine curve, as follows: Let axes be established as indicated in Fig. 1 so that the cosine curve is defined by

$$y = a \cos \frac{2\pi x}{\lambda} = a \cos kx \tag{1}$$

where

$$k = 2\pi/\lambda$$

Now

$$\xi = x + r \sin \theta$$

but, $-\tan \theta$ is the slope of the cosine curve at the point (x, y), or

$$-\tan \theta = -ka \sin kx$$

Hence

$$\sin \theta = \frac{ka \sin kx}{\sqrt{1 + k^2a^2 \sin^2 kx}}$$

and

$$\xi = x + \frac{kar \sin kx}{\sqrt{1 + k^2a^2 \sin^2 kx}} \tag{2}$$

Similarly,

$$\begin{aligned} \eta &= y + r \cos \theta \\ &= a \cos kx + \frac{r}{\sqrt{1 + k^2a^2 \sin^2 kx}} \end{aligned} \tag{3}$$

These parametric equations for the poid have involved no approximations. Unfortunately the elimination of x between them and the expansion of η in a Fourier series in ξ is extremely difficult, each coefficient involving the term-by-term integration of the product of three infinite series, none of which converges rapidly for the range of values in which we are interested.

An alternative method of solution was therefore sought. Chaffee[3] has described a simplified form of schedule analysis, applicable to even functions, which is capable of considerable accuracy and requires a knowledge of the coördinates of only a limited number of points. The poid is an even function, as indicated by its symmetry about either a maximum or a minimum point, so that, with the coördinates of only seven points in a half-wavelength, the amplitudes of the second and third harmonics may be determined within one or two per cent, and reasonably accurate values may be calculated for harmonics up to the sixth. This precision was deemed adequate for our purpose.

It was required, then, to determine values of η corresponding to the values of $k\xi$ prescribed by the harmonic analysis schedule. The values of x corresponding to these prescribed values of $k\xi$ were first obtained by successive approximations, assumed values of x being inserted in equation *2* until $k\xi$ was established with sufficient accuracy. These values of x for each prescribed point were successively inserted in equation *3* and the resulting values of η used to enter the harmonic analysis schedule. The relative amplitudes of the six harmonics were then obtained by simple arithmetic.

This method of computation, while laborious, requires no approximations except those inherent in the schedule analysis and these may be made as small as desired by computing a sufficiently large number of points. By making check calculations using as many as thirteen points for a half-cycle it was found that the "seven-point" analysis was indeed sufficiently accurate.

On reference to Fig. 1 it may be noted that the size and shape of the poid, and therefore the amplitude of each harmonic constituent of the poid, is given by three linear dimensions, a, r, and λ. On the other hand, the *shape* of the poid and the *relative* amplitudes of its harmonic constituents are determined by the two dimensionless ratios, a/λ and r/λ. Our subsequent discussion will be simplified if we take these ratios as $2\pi a/\lambda$ and $2\pi r/\lambda$ (*i. e.*, as ka and kr), and we may then say that the relative harmonic structure of the poid is a

function of the two independent variables *ka* and *kr*. It is necessary now only to calculate the distortion corresponding to all possible values of these two variables—a straightforward but tedious process.

The values of harmonic distortion so calculated might be plotted vertically over the *ka-kr* plane and constitute a characteristic surface whose distance above the horizontal plane is a measure of the harmonic distortion for the condition corresponding to the coördinates *ka* and *kr*. It is frequently convenient to represent such a warped surface by projecting onto the horizontal *ka-kr* plane contours of selected constant values of harmonic distortion. It is thus possible to represent on a single chart the entire range of tracing distortion met under all recording conditions. The computational labor involved in obtaining such a set of contours is reduced by the preparation of a family of intermediate curves, each showing harmonic distortion plotted against the variable *kr* with selected values of *ka* held constant for each of the intermediate curves. If horizontal lines are now drawn at the chosen values of the total harmonic distortion, they will cut the family of intermediate curves in a series of points which establish the pairs of coördinates for the points lying along the constant-distortion contour curve. These points are then transferred to the *ka-kr* plane and the contours drawn as exhibited by the dashed lines of Fig. 4. By this method the harmonic analysis of some thirty poids is sufficient to establish the contour set covering the entire useful range of the independent variables *ka* and *kr*.

It may be pointed out that the harmonic analysis schedule yields the *amplitudes* of the various harmonics. Inasmuch as reproducing systems are almost invariably velocity-responsive (either intrinsically, as in the electromagnetic, or through equalization, as in the piezoelectric) each harmonic amplitude is multiplied by its harmonic number before comparison with the amplitude of the fundamental, and the contour chart of Fig. 4 is then drawn in terms of the total root-mean-square harmonic velocity distortion.*

As suggested above, the dashed-line contours of Fig. 4 are directly applicable to reproduction from vertical-cut records, and their interpretation under specific recording conditions will be given in a later section. Before applying these results to the reproduction of

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* If $v_1, v_2, v_3, \ldots$ are the harmonic velocity components the total rms. distortion is defined as

$$H.D. = \frac{\sqrt{v^2{}_2 + v^2{}_3 + \ldots}}{v_1}$$

lateral-cut records we must consider in greater detail the geometrical relation between a laterally modulated groove and the stylus tip. Fig. 2 is a plan view and two typical cross-sections of a laterally modulated record groove. This groove is generated by a plane cutting surface which is always perpendicular to the axis of the unmodulated groove. There arises, consequently, a constriction in the width of the groove, measured perpendicular to its instantaneous direction, whenever the cutting needle is moving at an angle to the direction of the unmodulated groove. This is illustrated by the sectional views of the groove given at the bottom of Fig. 2. If such a groove be traced by a stylus that bears at least partially upon the groove sidewalls, it will be seen at once that the stylus must rise and fall twice during the tracing of each fundamental wavelength. This phenomenon appears to have been ignored or neglected in previous discussions of the so-called "pinch effect," but it leads to the necessary conclusion that *an ideal reproducer for lateral-cut records must embody sufficient vertical flexibility to enable the stylus to execute this motion faithfully.* This requirement appears even more severe when it is remembered that this vertical motion must be executed at twice the frequency of the fundamental groove modulation. In typical commercial reproducers for lateral-cut records there is no provision for vertical motion of the stylus relative to the tone-arm, with the result that the stylus must ride at some intermediate elevation above its normal position in the unmodulated groove. Since the mass of the reproducer head and arm is too large to be vibrated at signal frequencies, the stylus is driven into the groove in the "pinched" sections. This gouges out the groove walls, producing additional surface noise and altering the original groove shape. When the groove section is not "pinched" the stylus floats above the groove and is free to "rattle" since it is not necessarily in contact with either wall. With conventional reproducing apparatus this process continues until the pinched sections of the groove have been enlarged (involving the erasure of any small amplitude high-frequency modulation that may be superimposed), or the needle has been worn. The needle tip then rides at some constant level but is never thereafter positively driven by more than one groove wall at a time. Olney[1] has pointed out that distortions may arise from this condition. On the other hand, if the stylus point is sufficiently sharp to reach the rounded bottom of the "standard groove" the result is equally bad; while the tendency to vertical motion is minimized or

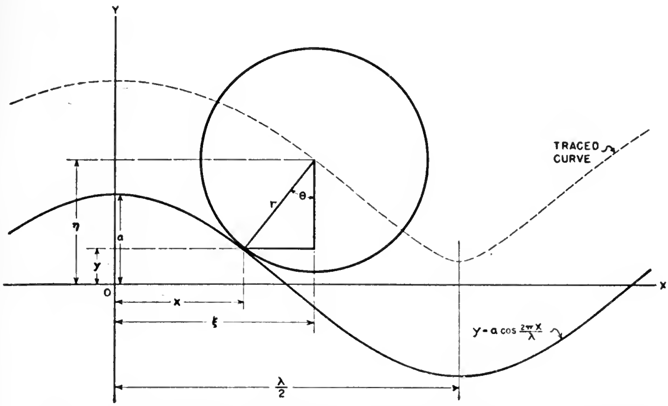

FIG. 1. Coördinates and nomenclature for the harmonic analysis of the curve ("poid") traced by the center of a circle sliding or rolling along a cosine curve.

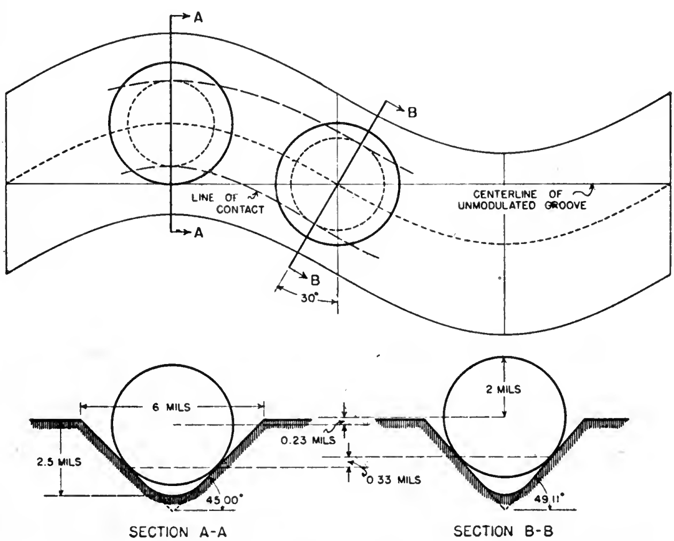

FIG. 2. Plan and sectional views of the assumed stylus bearing relations in a typical laterally modulated groove.

removed, the stylus is never positively driven by the groove. It is not possible to make an accurate quantitative analysis of the distortion introduced by the uncontrolled rattling of a stylus tip in a record groove, but it seems reasonable to assume that the distortion under such conditions will be at least as large as would be generated if the stylus were in continuous contact with the groove walls. More-

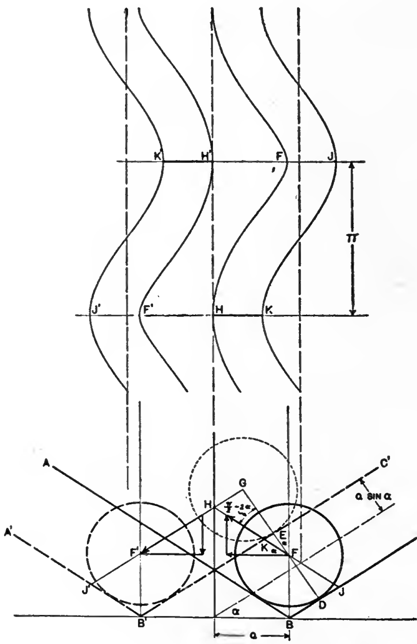

FIG. 3. Section and projected plan views illustrating the stylus displacement components during the tracing of a laterally modulated record groove.

over, the distortion generated by rattling would be inharmonic, and as this would contribute noise as well as signal distortion, we may conclude that an ideal reproducer whose stylus is positively driven by the groove walls will yield a lower background noise level.

It seems, therefore, that it is highly desirable in practice, and necessary for a mathematical analysis, to endow our assumed ideal lateral reproducer with such characteristics that it can execute the prescribed vertical motion faithfully, and we further assume and hold

as desirable that the stylus should be supported by the sidewalls of the groove. With a spherical stylus tip this does not lead to a large increase in needle bearing pressure in practice, and we assume here and throughout this discussion that no account need be taken of the distortion of the groove surface by the needle bearing pressure. When these conditions are satisfied we may discuss the components of stylus motion with the assistance of Fig. 3.

Consider that BC and $B'C'$ are the projections onto the plane of the paper of the two extreme positions of a radial section of one wall of a groove that is modulated laterally with an amplitude a. As the record rotates, this groove wall is generated as a wavy surface having a sinusoidal profile. The curve traced by the center of a ball sliding upon this surface, if projected upon a plane perpendicular to BC, as indicated by DG, will be a poid which will have a maximum and a minimum at G and F, respectively. In this plane through DG, perpendicular to the paper, the amplitude of the sine wave is $a \sin \alpha$, and the poid may be represented by

$$\eta' = a_1 \sin \alpha \cos k\xi + a_2 \sin \alpha \cos 2k\xi + a_3 \sin \alpha \cos 3k\xi + \ldots \qquad (6)$$

This poid may be projected upon a plane parallel to AB, such as the one through HJ, by dividing equation *6* by

$$\cos (\pi/2 - 2\alpha) = \sin 2\alpha = 2 \sin \alpha \cos \alpha$$

Its equation now becomes,

$$\eta = \frac{a_1}{2 \cos \alpha} \cos k\xi + \frac{a_2}{2 \cos \alpha} \cos 2k\xi + \frac{a_3}{2 \cos \alpha} \cos 3k\xi + \ldots \qquad (7)$$

This equation expresses the motion of the sphere caused by the change in position of the sidewall represented by BC and $B'C'$, and since the motion is projected upon a plane parallel to the opposite sidewall it may be divided into components, in both the vertical and horizontal planes, which are independent of any simultaneous motions of the opposite sidewall. For example, the horizontal component of the motion is given by

$$\eta'_{\mathrm{H}} = \frac{a_1}{2} \cos k\xi + \frac{a_2}{2} \cos 2k\xi + \frac{a_3}{2} \cos 3k\xi + \ldots \qquad (8)$$

The corresponding equation for the component of motion induced by the opposite sidewall is identical except for direction and a phase difference between the two poids. It is to be noted that there is a phase displacement of 180 degrees in the equation of the motion due to the sidewall indicated by AB; that is, the maximum of one poid

occurs simultaneously with the minimum of the other. This is indicated by the plan view, shown in the upper part of Fig. 3, which represents the projection onto the horizontal plane of the sine curve profile of the groove walls and the poids generated in the planes through HJ and HJ'. The horizontal projection of the poid generated by the wall AB is directed oppositely to that generated by the wall BC, as viewed, say, from the center of the record, because the sphere is being pushed away from the center of the record in one case and toward it in the other. The expression for the horizontal components of motion generated by the second poid is given, therefore, by,

$$\eta''_H = -\frac{a_1}{2}\cos(\pi + k\xi) - \frac{a_2}{2}\cos 2(\pi + k\xi) - \frac{a_3}{2}\cos 3(\pi + k\xi) - \ldots$$

$$= \frac{a_1}{2}\cos k\xi - \frac{a_2}{2}\cos 2k\xi + \frac{a_3}{2}\cos 3k\xi - \ldots \tag{9}$$

As shown by the directed arrows in Fig. 3, when the displacement of the groove is away from the center of the record the stylus is forced to move part way in this direction by the displacement of the inner groove wall, and allowed to slide the remainder of the way by the retreat of the other wall.

The total lateral motion of the stylus is, therefore, the sum of the motions induced by both sidewalls, or

$$\eta_H = a_1 \cos k\xi + a_3 \cos 3k\xi + \ldots \tag{10}$$

This yields at once the important result that the even harmonics of the fundamental frequency are cancelled out of the lateral motion of the reproducer stylus. Returning to equation *7* and projecting the poid on the vertical plane through H by multiplying the equation by $\sin \alpha$, we find for the component of vertical motion induced by the sidewall BC,

$$\eta'_V = \frac{a_1 \tan \alpha}{2}\cos k\xi + \frac{a_2 \tan \alpha}{2}\cos 2k\xi + \frac{a_3 \tan \alpha}{2}\cos 3k\xi + \ldots \tag{11}$$

For the component of motion induced by the opposite sidewall we have still the 180-degree displacement in phase, but the direction of the displacement represented by the poid is in this case the same, that is, upward. Hence, for the wall AB,

$$\eta''_V = \frac{a_1 \tan \alpha}{2}\cos(\pi + k\xi) + \frac{a_2 \tan \alpha}{2}\cos 2(\pi + k\xi) +$$
$$\frac{a_3 \tan \alpha}{2}\cos 3(\pi + k\xi) + \ldots$$

$$= -\frac{a_1 \tan \alpha}{2} \cos k\xi + \frac{a_2 \tan \alpha}{2} \cos 2k\xi - \frac{a_3 \tan \alpha}{2} \cos 3k\xi + \dots \qquad (12)$$

As before, the resultant vertical motion is given by the sum of the components of motion induced by the two sidewalls and is

$$\eta_V = a_2 \tan \alpha \cos 2k\xi + \dots \qquad (13)$$

We may, therefore, extend the conclusion stated above as follows: *the lateral motion of a stylus tracing the groove of a lateral-cut record is determined by the fundamental and odd harmonics only of the poid characterized by the groove amplitude, the wavelength, and the needle radius; the even harmonics of the poid appear as vertical motion and constitute the "pinch" effect.*

It may be pointed out for contrast that in the corresponding case of a vertical-cut record the motion of the two sidewalls is in phase, the maxima of the two poids occur simultaneously, the lateral motion is completely cancelled out, and all the harmonic constituents of the poid enter into the expression for the total vertical motion.

The difference in the distortions arising in the reproduction of these two types of groove modulation is emphasized by the observation that positive drive of the stylus tip by *both* sidewalls of the groove yields the usual advantages of a push-pull system, with the result that *a large part of the distortion inherent in the reproduction of vertical-cut records is entirely absent in the reproduction of lateral-cut records when a satisfactory lateral reproducer is employed.* The latter qualification is added to indicate that the specifications of the ideal lateral reproducer here assumed are somewhat unconventional, and these reduced distortion levels are not to be expected generally with the present types of conventional lateral reproducers.

On this basis we may return to the original data upon which the dashed contours of Fig. 4 were based and compute the root-mean-square value of the odd harmonics, prepare a set of intermediate curves, and establish the solid-line contours as characteristic of the distortion generated in the reproduction of a lateral-cut record.

CHARACTERISTICS OF THE *ka-kr* CHART

We turn now to a more detailed discussion of the chart upon which contours of constant distortion are represented. A choice of logarithmic scales for the two coördinate axes endows the contour chart with the interesting property that almost all the characteristic quantities, in terms of which the performance of a phonograph system

is analyzed, are represented on the chart by straight lines which are horizontal, vertical, or inclined at 45 degrees to the principal axes.

(*A*) The ordinate scale, *ka*, gives directly the ratio of the maximum cyclic stylus velocity to the tangential groove velocity, so that, other factors being held constant, a vertical line on the chart represents a change in the recorded velocity amplitude. Since the ordinate scale is logarithmic, a uniform scale, as appended to the right-hand margin of the chart, may yield the velocity amplitude in decibels referred to the tangential groove velocity as zero level. Such a scale is convenient for estimating changes in the recorded level.

The maximum radial velocity of the stylus occurs as the center-line of the groove crosses the line of the unmodulated groove, and the cutting angle is therefore a maximum at that time. The tangent of this angle is given directly by *ka* so that a subsidiary scale may be appended to the upper right-hand corner of the contour chart establishing the minimum value of the clearance angle of the cutting stylus required in order that the groove be cut without interference from the trailing edge.

(*B*) A 45-degree line on the contour chart extending from the lower left to the upper right is a line corresponding to a constant ratio of the amplitude of groove modulation to the stylus tip radius. Along such a sloping line, drawn for a given ratio, a/r, one may plot frequency increasing upward to the right or tangential groove velocity increasing downward to the left, according as one or the other variable is assumed constant.

(*C*) As indicated under *A*, a horizontal line on the contour chart is a line of constant velocity amplitude. Inasmuch as this represents the usual ideal recording situation it represents an important locus, and, in general, frequency increases toward the right along such a horizontal line. There will always be, for any assumed standard conditions of record speed, maximum amplitude, and stylus radius, some record radius for which a horizontal line would allow frequency to be read directly from the scale of abscissa, in kilocycles. This record radius is frequently an unusable one, but the reference line so defined is convenient in that a frequency may be located on this line and a projection made along a 45-degree line downward to the left to the record radius desired.

(*D*) A 45-degree line extending from the lower right to the upper left is a line for which the product of *ka* and *kr* is constant. It can be shown that along such a line the ratio of the radius of the needle tip

to the minimum radius of curvature of the record groove is constant. For example, a line having this slope and passing through the (*1*, *1*) point is the line for which the ratio of these curvatures is unity. All traced curves represented by points lying above and to the right of this line are poids having a cusp.

APPROXIMATE GENERALIZATION OF THE DISTORTION DATA

One striking characteristic of the constant-distortion contours exhibited in Fig. 4 is the fact that, except in the upper portion corresponding to extreme values of velocity amplitude, the contours are straight lines inclined at 45 degrees to the principal axes. So far as this is an accurate description of the contours, we may derive certain general relationships by examining the distortion as this family of 45-degree lines is cut by other lines representing loci of constant parameters of the recording conditions.

(*1*) As suggested above under *D*, a 45-degree line having the orientation of the contours is a line along which the ratio of the needle tip radius to the minimum radius of groove curvature is constant. Examination of the contours indicates that for vertical reproduction the total distortion varies linearly with the ratio of these radii. For lateral reproduction the total distortion is smaller and varies as the square of this ratio. It may be pointed out that if the frequency, the groove speed, and the needle tip radius are constant, then the ratio of the groove and needle tip curvatures, and hence the total distortion for vertical reproduction, is a linear function of the recorded amplitude. For lateral reproduction the corresponding total distortion is proportional to the square of the recorded amplitude. The ratio of the radii of curvature has frequently been offered as a criterion of the upper limit of frequency that could be reproduced satisfactorily. Our study indicates that this is indeed a satisfactory rough criterion of distortion, and it may be seen from the chart that equality in these radii corresponds to approximately 40 per cent total distortion for vertical reproduction and 20 per cent total distortion for lateral reproduction. If one selects 10 per cent total distortion as a tolerable limit, the required ratios are approximately $^3/_5$ for lateral and $^1/_5$ for vertical.

The velocity amplitude of any harmonic component, relative to the fundamental component, may be determined by the simple empirical relationship,

$$H_n = \frac{(kakr)^{n-1}}{n} \qquad (14)$$

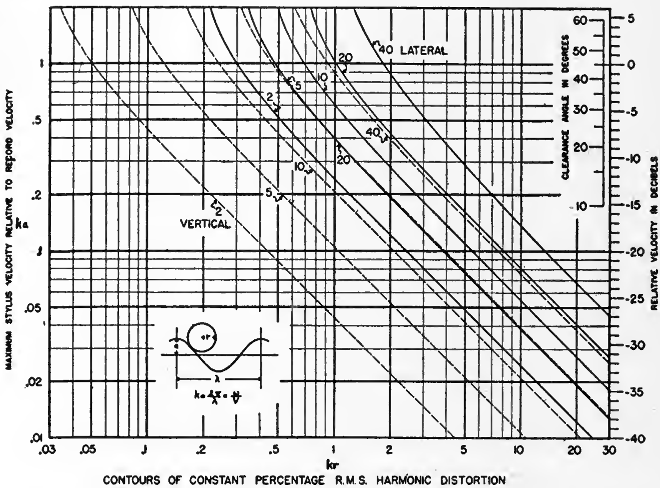

FIG. 4. Universal chart, for velocity-responsive systems, displaying contours of constant rms. total harmonic distortion, for both vertical- and lateral-cut records, plotted against the dimensionless independent variables *ka* and *kr*.

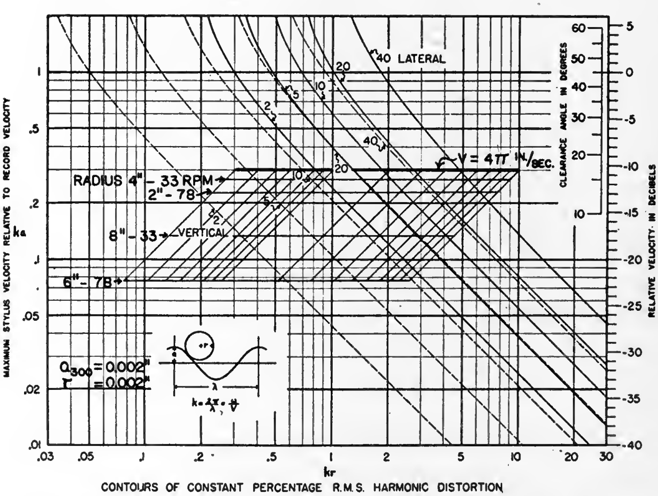

FIG. 5. Recording loci superimposed upon the *ka-kr* chart. Along the heavy reference line for $V = 4\pi$ in./sec. the frequency may be read directly in kilocycles from the abscissa scale.

where n is the number of the harmonic. Comparison of this relation with the preceding approximate statements about the variation of the total harmonic distortion confirms the fact that the principal component of distortion for vertical reproduction is a second harmonic, while the principal distortion component for lateral reproduction is a third harmonic.

(*2*) A horizontal line, as discussed under *C* above, is a line of constant velocity amplitude, along which frequency increases toward the right. Examination of the chart reveals that total distortion varies directly with the frequency for vertical reproduction and as the square of the frequency for lateral reproduction. On the other hand, if the frequency and other reproducing conditions remain constant, then points corresponding to a variation in needle tip radius will lie along the horizontal line, and the total distortion will increase linearly with the needle tip radius for vertical and as the square of the needle tip radius for lateral.

(*3*) If both the recorded velocity amplitude and the needle tip radius be held constant as either the record radius or the record speed is varied, the values of both ka and kr change simultaneously, so that the contour curves are crossed along a 45-degree line extending from lower left to upper right. Examination of the chart then indicates that, for vertical reproduction, the total distortion varies inversely as the square of either the record radius or the record speed, according as one or the other of the two variables is held constant. For lateral reproduction the total distortion increases inversely as the record radius or record speed raised to the fourth power.

Summarizing these approximate relations, we may say that in general the distortion obtained in lateral reproduction is always lower than in vertical but that it varies more rapidly with the parameter introducing the distortion. Two additional characteristics of the contour chart may be pointed out in this connection. The total distortion for either lateral or vertical shows a distinct "saturation" as the distortion approaches some high value. In the case of lateral this saturation value is approximately 48 per cent; for vertical the saturation value is nearly 80 per cent. It will be noted that no contours have been drawn on the chart indicating the reduction in the amplitude of the fundamental component as the distortion increases. This omission was made in the interests of avoiding confusion in the contour chart. The data indicate that the contour lines corresponding to 20 per cent distortion for lateral or 40 per cent distortion for

vertical correspond roughly to a reduction in fundamental amplitude of approximately 0.7 db. in either case. It is obvious therefore that the total harmonic distortion will have reached intolerable proportions before there is any significant reduction in fundamental amplitude. It follows that an appreciable "quality" difference between the inside and outside radii of a recording, detectable as a loss in high frequencies, must inevitably be accompanied by a serious increase in harmonic distortion and should never be tolerated in a high-fidelity system. The provision of variable equalization for recording at the inside of a record, which has been seriously proposed, appears to be defensible only as a partial corrective for the characteristics of a recorder that relies principally upon the recording medium for damping.

DISTORTION ANALYSIS FOR TYPICAL RECORDING CONDITIONS

We shall now illustrate the application of the contour chart to an evaluation of the distortion arising under typical recording conditions. We shall assume for this purpose that the record is cut with 100 grooves per inch, each groove being 6 mils wide at the surface of the record, 2.5 mils deep, with an included angle of 90 degrees, and having a bottom surface rounded to a radius of curvature of approximately 1.25 mils. Under these conditions the assumptions regarding support of the stylus tip by the sidewalls of the groove may be satisfied by a stylus having a tip radius of 2 mils. The maximum allowable amplitude of modulation, determined by the groove spacing, will also be 2 mils. If the record is vertical-cut, only the assumed values of a and r are material. For the standard recording conditions we shall assume that the amplitude of the cut is constant for frequencies up to 300 cycles, and that the velocity amplitude is maintained constant at all higher frequencies. The constant-amplitude portion of this recording locus is represented by the left-hand margin of the parallelogram superimposed upon a *ka-kr* chart in Fig. 5. Frequency increases upward along the left-hand border of the parallelogram, and the frequency 300 cycles, at which the recording locus breaks into a horizontal line, occurs at some point dependent upon the tangential groove velocity. Four such horizontal lines are illustrated, corresponding to the inside and outside radii of typical 33 and 78 rpm. recordings. For the assumed stylus tip radius the reference line along which frequency may be read directly from the scale of abscissas occurs at a groove velocity of 4π inches per second. A 45-degree system of projection coördinates is based upon this ref-

erence line and allows any frequency, established along the reference line, to be referred to the appropriate record radius. For example, if it is desired to determine the distortion at 5000 cycles, 2-inch radius, 78 rpm., the procedure is as follows: follow the ordinate $kr = 5$ upward to the standard reference line, trace downward along the 45-degree line to its intersection with the horizontal corresponding to 78 rpm., 2-inch radius, interpolate between the contours to determine

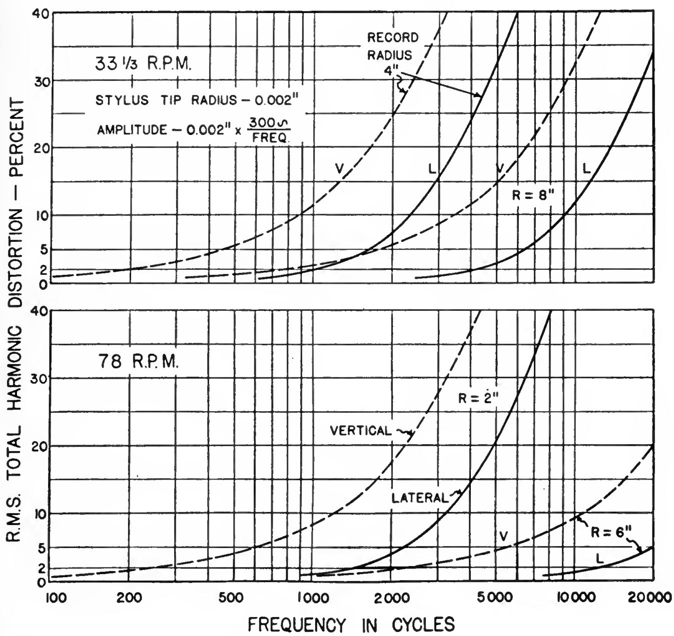

FIG. 6. Total distortion plotted as a function of frequency for constant velocity amplitude and typical recording conditions.

the total (lateral) harmonic distortion as 22 per cent. Following this procedure we may derive the data exhibited in Fig. 6, showing the rms. total distortion at typical inside and outside radii for 33- and 78-rpm. recordings, both lateral- and vertical-cut. These curves exhibit clearly the marked superiority of lateral-cut over vertical-cut with regard to distortion, and indicate also the more rapid increase in distortion for lateral-cut as the frequency increases. One may be pardoned for wondering, on examination of the curves of Fig. 6, how it can be that records sound as well as they do in view of these serious

distortions. The explanation of this anomaly lies in the fact that speech and music by no means present the recording medium with the necessity of recording a constant velocity amplitude at all frequencies. The valuable data of Sivian, Dunn, and White[4] on the intensity distributions in speech and music are available for an evaluation of this situation. We present our interpretation of these data in Fig. 7 in order to avoid any ambiguity about the application of this correction. The two curves for speech and music are arbitrarily shifted vertically to have the same peak amplitude inasmuch as an adequate volume indicator should indicate these peaks and provide a common basis for level control. The manner of applying these correction data to the distortion contours consists in locating fre-

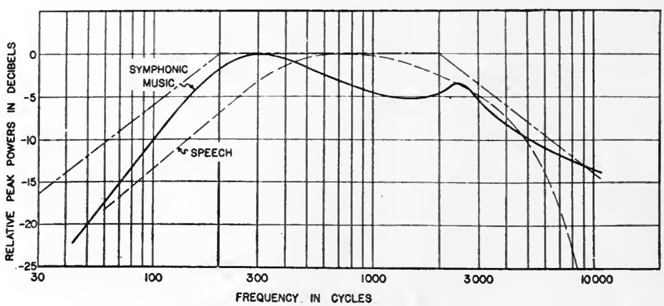

FIG. 7. Peak power as a function of frequency (from the data of Sivian, Dunn, and White) used to evaluate the distortion in recorded speech or music.

quencies along the broken-straight-line recording locus as before, but interpolating between the contours for a point shifted vertically downward by the number of decibels plotted for the corresponding frequency in Fig. 7. These corrected values of distortion might be shown along with the curves of Fig. 6 for constant velocity amplitude, but for the illustration of an alternative method of exhibiting these data, we have prepared the curves of Fig. 8. These show the minimum value of record radius that will allow the music spectrum of Fig. 7 to be recorded with a total distortion not exceeding 10 per cent, plotted as a function of the frequency. The corresponding correction for speech would yield similar curves but without further rise beyond 2500 cycles. The nearly horizontal portions of the curves of Fig. 8 indicate that the present accepted standard inside radii for lateral-cut transcription and commercial pressings are ac-

ceptable for the satisfaction of the 10-per cent distortion limit, but that, for the assumed amplitude of groove modulation, the 33-rpm. vertical transcription record is not capable of meeting the 10-per cent distortion specification without a reduction in needle tip radius.

EXPERIMENTAL CONFIRMATION OF THE DISTORTION DATA

In connection with his study of vertical reproduction, DiToro[2] has measured the relative amplitude of the second harmonic for values of *ka* and *kr* lying in the lower right-hand corner of our contour diagram. The agreement between his experimental observations and our calculations is quite good for this type of measurement, and may be considered adequate to confirm the dotted contours of Fig. 4.

In view of the significantly lower distortion revealed by this study to be characteristic of lateral reproduction, it seems worth while to present some experimental data confirming these predictions. A direct-reading distortion meter operating at 400 cycles was used, and in order to simulate the conditions that would occur at a higher frequency at normal groove velocities, records were made and played back at speeds of 9 and 13 rpm. By thus shortening the wavelength, values of *ka* as high as 0.7 were obtained with *kr* no greater than 2, so that we were able to investigate the most useful part of the *ka-kr* diagram. A new type of lateral reproducer[5] satisfying the conditions assumed in the distortion analysis was employed.

The test grooves were cut on lacquer-coated records. The cutting head used relies to some extent upon the record material for damping and so did not yield a constant amplitude at all groove speeds. This was taken into account in constructing the solid "calculated" curves of Fig. 9, the larger amplitudes being measured optically while the smaller were found by measuring the relative reproducer outputs at the fundamental frequency. Measurements were made at various record radii for two record speeds and for three different recording levels. The results are shown in Fig. 9 and seem to provide a wholly satisfactory verification of the mathematical analysis.

The residual distortion levels of 2, 5, and 10 per cent, shown at the right-hand side of Fig. 9, may be attributed to the recording equipment, and principally to the recording head itself. It is, however, obvious that for the smaller values of tangential groove velocity tracing distortion is the predominant factor, and that its magnitude has the calculated value. It may also be concluded that not only were the reproducer specifications satisfactorily met, but that the

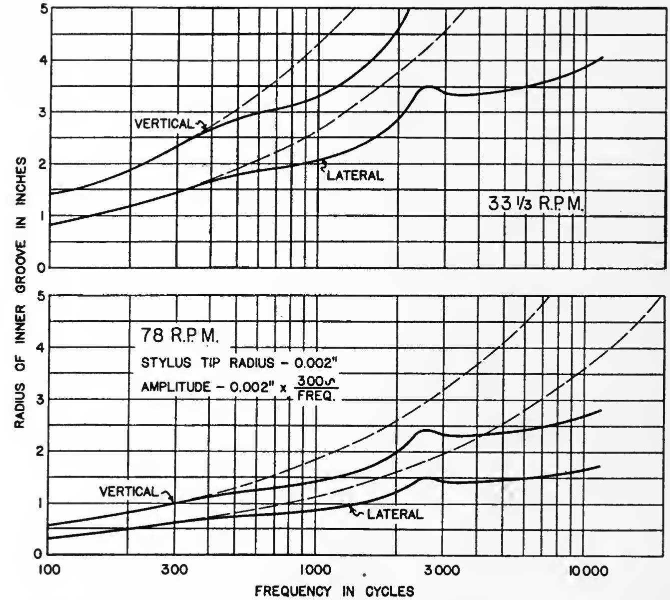

FIG. 8. Distortion data for the music spectrum (solid lines), exhibited by plotting the minimum groove radius for which the distortion will never exceed 10 per cent. The dashed curves correspond to constant recorded velocity amplitude.

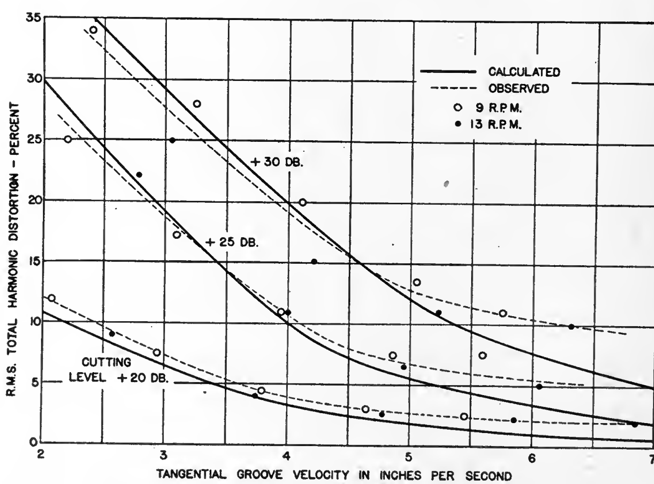

FIG. 9. Experimental data verifying the calculated distortion for lateral reproduction.

assumption made in the analysis regarding the negligibility of momentary deformations of the groove sidewalls was justified.

CONCLUSIONS AND RECOMMENDATIONS

A method of reducing the effective surface noise level has been suggested, and in some cases utilized, that consists in predistorting the recording frequency characteristic in such a way that high-frequency components are recorded at an increased level. Complementary equalization in the reproducing system restores the original balance and at the same time suppresses a portion of the surface noise generated in reproduction. The distortion contour chart provides a method of evaluating the effect upon harmonic distortion of this type of alteration of the frequency response of the recording system. We have indicated above that in vertical-cut records the total distortion is a linear function of the recorded amplitude so that it would appear at first sight that it would be permissible to enhance the high frequencies in recording, allowing the distortion to increase linearly, and in the complementary equalization not only restore the original tonal balance but also return the relative harmonic distortion to the original value it would have had without modification. This is indeed a useful method of reducing effective surface noise so long as its use does not increase the distortion beyond the range for which the second harmonic, which is the component varying linearly with amplitude, is the principal distortion factor. If significant distortion terms higher than the second occur, not only will they increase more rapidly, and hence not be proportionately removed by the reproducing equalization, but the higher terms will also contribute cross-modulation products which would not have been present at the original distortion level. Inasmuch as the distortion level is already high for vertical reproduction under typical conditions of groove amplitude and stylus radius, it appears that the gain to be derived from a predistorting technic is rather limited. On the other hand, in the case of lateral groove modulation, the total distortion increases with the square of the recorded amplitude, so that an increase in distortion introduced by modification of the recording frequency characteristic would not be compensated by complementary equalization in the reproducing system. It appears, therefore, that in this case the predistorting technic can never be employed unless the needle tip radius can be reduced to such an extent that tracing distortion is a negligible factor in the overall distortion of the system.

The effect of cross-modulation mentioned above should be emphasized in connection with the curves of Figs. 6 and 8. It is probable that we are seldom if ever interested in the harmonic distortion components accompanying fundamental frequencies higher than 4000 to 6000 cycles. On the other hand, the cross-modulation products that accompany such distortion are of considerable interest, and, although difficult to analyze accurately, are approximately of the same magnitude as the harmonic components themselves. Thus, all the distortion data presented above for frequencies higher than about 5000 cycles are to be interpreted as indicative of the magnitude of the cross-modulation components. These components are observed aurally in wide-range systems as a "burr" accompanying loud passages. The sum and difference tones, being inharmonic, are more objectionable than comparable harmonic overtones. Thus, even though the overtones of these high frequencies may be outside the transmission band of the reproducing channel, the distortion limits that should be imposed upon a high-fidelity system are more severe than for the lower frequencies. These considerations indicate that the 10-per cent distortion limit assumed for the curves of Fig. 8 is too high to be acceptable if the overall system response is to extend significantly above 5000 cycles.

A second conclusion can be drawn from the foregoing exhibition of the distortion performance of typical vertical and lateral recording conditions, based upon the broken-straight-line envelope of the peak-power correction curve shown in Fig. 7. It may be seen from this curve that the low-frequency peak amplitude falls off by slightly more than 6 db. per octave for frequencies below 250. On the other hand, this is exactly the reduction in velocity amplitude that one seeks to gain by altering the standard cut from constant velocity to constant amplitude for frequencies below 250–300 cycles. The conclusion is that there is no real necessity for altering the character of the cut from constant velocity to constant amplitudes at this low frequency. If the "standard" cut is maintained at constant velocity amplitude for the entire spectrum the greatest danger of "overcutting" would still occur in the neighborhood of 300 cycles, just as under the present "standard" conditions, but it would then become unnecessary to provide electrical equalization for the range below 300 cycles, as is at present required with high-fidelity recording and reproducing equipment.

A third conclusion and recommendation may be based upon a pos-

sible modification of the "standard" groove cross-sectional shape used in lateral recording. It seems almost certain that a lateral reproducer having the necessary vertical mobility assumed in the foregoing analysis can be designed to exert extremely light forces upon the groove wall. If this feature of the design can be carried far enough there is no reason why the needle tip radius may not be reduced to less than 1 mil. If these conditions are satisfied there is then no necessity for (*a*) a total groove depth of 2.5 mils, or (*b*) such a large rounded bottom portion of the groove. For example, a sharp bottomed (or very slightly rounded) groove 2 mils wide should be adequate to provide tracking for a reproducer capable of operating satisfactorily with a stylus tip radius of 0.75 mil. If the desired maximum amplitude of groove modulation be retained at 2 mils, there would be a net saving of some 40 per cent of the available record surface, so that a groove pitch of 175 per inch could be used.

TABLE I

Playing Time in Minutes

Size and Speed of Record	r = 2 Mils 100 Grooves/ Inch	r = 0.75 Mil 175 Grooves/ Inch	r = 2 Mils 100 Grooves/ Inch	r = 0.75 Mil 175 Grooves/ Inch
	10-per cent distortion		*5-per cent distortion*	
10″—78 rpm.	4.2	8.8	3.8	8.3
12″—78 rpm.	5.5	11.0	5.1	10.5
16″—78 rpm.	8.1	15.5	7.7	15.0
12″—33 rpm.	6.9	19.2	4.8	16.8
16″—33 rpm.	12.9	29.7	10.8	27.3

Such groove spacing would allow as much as 30 minutes of recording on each side of a 16-inch, 33 rpm. transcription record, with no sacrifice in the present available recorded levels, and with a material reduction in total harmonic and cross-modulation distortion compared with present transcription records. For a 12-inch, 78-rpm. record suitable for home use a total of 11 minutes of recording would be available with a similar reduction in total distortion as compared with current practice. These reductions in harmonic distortion and the gain in length of playing time stem principally from the reduction in radius of the needle tip and the consequent desirability of reducing the width of the recorded groove at the record surface. Table I exhibits a comparison of the playing times available with a 10-per cent and a 5-per cent distortion limit, for lateral-cut records.

The gain in playing time and usefulness of the convenient 12-inch, 33-rpm. record is worthy of note, as is the fact that the lower the permissible distortion the greater is the advantage of the proposed narrow groove and small stylus tip.

To achieve comparable reductions in distortion for the present type of standard, round-bottomed, lateral-cut groove, Mr. Olney has suggested to us the possibility of using a needle tip having either an elliptical cross-section presenting a small radius of curvature to the groove wall, or, alternatively, a needle tip section consisting of a flat circular disk perpendicular to the groove axis with the edges rounded to a small radius.

Because this study has enabled us to predict the conditions necessary to its success, we wish to call attention here to the system of controlled volume expansion illustrated in Fig. 10. This method has been proposed before as a means of avoiding volume distortion, but it does not appear to have made its way into the art as yet.

As the figure indicates, the only modification necessary in the recording technic is the introduction of a constant tone at a point in the system preceding the gain control which is used to compress the program material. This pilot tone must be of such a frequency that it is within the pass-band of the recorder and reproducer, but outside of the desired program band. In the diagram we suggest a 12-kc. pilot tone, to be used with a 10-kc. program channel. No other change need be made in the recording technic.

When such a record is reproduced with conventional equipment not responsive to the high-frequency pilot tone the performance is entirely normal and the user need not be aware that the record is in any way unusual. This seems to be an important feature since the pilot tone could be introduced in commercial records without impairing their value for use with existing phonographs. On the other hand, if the user wishes to take advantage of the enhanced volume range it is necessary only to employ a reproducer capable of responding to frequencies as high as that of the pilot tone, to segregate the pilot tone with a filter, rectify it, and apply it to the automatic volume control circuit of an amplifier similar to those ordinarily used in radio receivers. This automatic volume control operates to maintain a constant level of the pilot tone at the amplifier output. Since this condition is that which obtained during recording, the original volume range will have been restored. That this is possible may be made clearer by consideration of the fact that we now have two independent

recorded and reproduced channels, operating in synchronism. By proper use of these two channels we are able to add their volume ranges while listening to the program material carried by one of them.

The *ka-kr* chart of Fig. 4 indicates that the high-frequency pilot tone will be subject to considerable distortion (and cross-modulation with the program material) unless it is recorded at a level substantially less than that of the program. In spite of this restriction the effective signal-to-noise ratio for the pilot channel may be as high as for the program channel if the control-tone is separated out with a filter whose pass-band is no wider than necessary to guard against

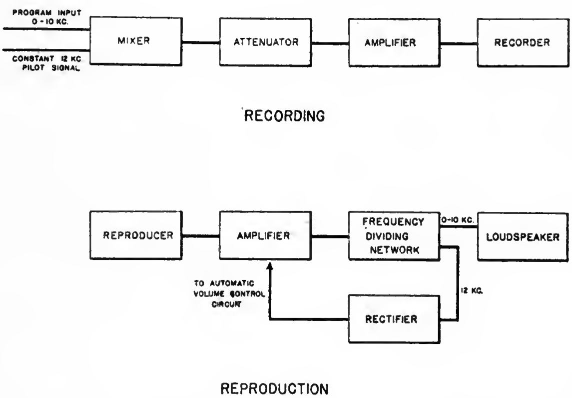

FIG. 10. Diagram illustrating system for controlled volume expansion, capable of restoring full dynamic range of original program material.

variations in turntable speed, and if the time-constant of the automatic volume control circuit is large enough to smooth out the irregularities of surface noise.

In brief, such a system of controlled volume expansion can furnish an accurate complement to the compression necessary in recording, and provide for the re-creation of the desired program in its full dynamic range. At the same time, it should be emphasized that such records would remain as satisfactory as any of those in common use when reproducing facilities for expansion are not available.

As an alternative method of utilizing a second recorded channel, it may be pointed out that if it is undesirable to re-create the full dynamic range of the original material the control channel may be used to provide volume inflection while the program is recorded well

above noise level at all times. While such records could be used only with reproducing equipment designed especially for them, they would provide phonographic reproductions entirely free from the audible effects of surface noise.

In conclusion it may be said that a principal result of this study has been the recognition and analysis of a large latent advantage, with regard to distortion, inherent in the lateral type of groove modulation. While not all these indicated gains are realized by the present conventional lateral-cut technic, we hope that new reproducer designs and a study of these geometrical relations will furnish some guidance for significant improvements in the fidelity and usefulness of disk records.

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DISCUSSION

MR. MACNAIR: The kind of distortion on hill-and-dale records that was analyzed in the paper was discussed qualitatively at the Fall, 1931, Meeting of the Society (*J. Soc. Mot. Pic. Eng.*, Feb., 1932, p. 143). A quantitative analysis of it appeared last year, and again we have a beautiful analysis of the subject presented to us this morning.

In Fig. 1 the lower curve is a sine wave, showing the shape of the bottom of a groove cut in a hill-and-dale record. When a stylus of finite radius traces the sine curve, there appears in the electrical output of the reproducer a signal corresponding to the upper curve having the characteristics that were mentioned by Mr. Pierce, namely, broad on the top and sharp at the bottom. It is therefore not a sine wave, and contains certain distortion products that were not in the original cut record.

There are several possible ways to correct for this kind of distortion. One is simply to dubb with the circuits poled properly. If one records the signal picked up from the reproducer, this upper shaped wave is recorded in the wax. But in doing this the circuit should be properly poled so as to cut the signal in the wax as illustrated by turning Fig. 1 upside down. If the last record is now traced with a stylus of the same size, the signal reproduced will be the original sine wave.

What has been done, then, is, when playing the record, to get from the reproducer a signal that is, so far as this kind of distortion is concerned, exactly the sine wave with which you started, a true picture of the originally recorded signal.

There are other possible ways to take care of this distortion, but the way described, namely, a dubbing process with the circuits properly poled, is the easiest to present here. Whether the distortions are of an objectionable magnitude depends, as the author pointed out, upon the recording, the level, and other conditions of the process, and also upon the purposes for which the recorded material is to be used. This method of greatly reducing this form of distortion has been available for some years.

MR. PIERCE: In order properly to reverse the poid this way it is, of course, necessary to have a transmission band that will pass all the harmonics generated in the original poid. In the extremely high-frequency cases, 5000–10,000 cycles, it may well require fourth and fifth harmonics in order to do this, which calls for a recording technic of rather remarkable excellence to do it properly.

A rather worse objection is that cross-modulation products, sum and difference tones (particularly difference tones), appear in the output through this phenomenon. They are rather difficult to analyze, but may be taken as more or less of the order of magnitude of the harmonic distortion. However, it is impossible to reproduce these cross-modulation products accurately the second time by this dubbing procedure, which is very unfortunate because they are the worst offenders so far as hearing is concerned. Ten to 15 per cent of pure harmonic content is tolerable, but when signals having those energies appear at random frequencies not associated with the material being reproduced, the effect upon the ear is a familiar burring, an unpleasant form of distortion that is heard when a commercial record is played through a 10,000-cycle channel, a way it is not originally intended to be used.

MR. COOK: Have you investigated the magnitude of the distortion which might result from a lack of needle tangency to the record groove?

MR. PIERCE: Not very much, except to investigate it experimentally. We found it was not a very serious subject on play-back, but did make quite a bit of difference in recording. Mr. Olney has made a rather good analysis of the subject, published, I think, in *Electronics* last year, which indicates that with reasonable precaution it can be kept down so well as to be practically out of the picture.

MR. COOK: I assume you refer to the use of an offset pick-up head placed at an angle to the tone-arm. It is interesting to note that both these expedients were employed by the Brunswick, Balke, Collender Co. who, it is believed, first proposed and used them in their first commercial electrical phonographs.

MR. PIERCE: That form of correction is entirely applicable. I might point out one other thing that Mr. Olney has suggested, which is the use of stylus tips of non-spherical shape, so that they present to the edge of the groove a smaller radius than they have in other dimensions.

MR. COOK: I was interested in your recommendation for the use of a control tone. My first acquaintance with it was while with the RCA. The results they obtained were impressive and, as Mr. Pierce has reported, it represents a desirable improvement. Their work with it was mentioned at the 1935 Spring Convention in Hollywood in a paper entitled "A Consideration of Some Special Methods for Re-Recording," *J. Soc. Mot. Pict. Eng.*, **XXV** (Dec., 1935), No. 6, p. 523.

MR. PIERCE: It can be added to present technics so simply that it is worth thinking about.

MR. DAVEE: For the past two and one-half years or so I have been connected with the World Broadcasting Company. You probably have heard their transcribed records over the radio, probably the program of Chevrolet with Graham MacNamee. I did not appreciate that this burring sound you are discussing was there. In all program work of that kind a certain amount of re-recording and dubbing has to be done, as in motion picture work, and as a result we have been using this poled dubbing scheme regularly.

MR. KELLOGG: The correction obtainable by correctly poled dubbing, or by any method that attempts to precompensate and give back the desired wave, involves some extreme difficulties, and while I would not for a moment deny that with reasonably good channels it would always be helpful, I had not, until this morning, realized that it has ever been practically applied, unless the dubbing were necessary for other purposes. It involves, for example, such difficulties as providing (when you reach the limiting curvature) infinite acceleration of the cutting stylus.

In lateral recording it appears that an analysis based upon purely geometrical relations leaves out so many important factors that its predictions can not be verified by tests.

MR. HASBROUCK: In Fig. 2 I noticed that the stylus was shown as not reaching the bottom of the groove. The groove that we use, and which is generally used for transcription work, has a radius at the bottom. The straight sides are rather short compared with the radius, and we attempt to contact the spherical portion of the stylus completely on the bottom. In that way we distribute the weight most uniformly and reduce wear and so forth.

I wonder whether any improvement is found in riding the straight sides of the groove, and whether it would not increase the wear on the record as well as distortion. The question of cold flow of the record material was not mentioned. It is quite pronounced; so much so, in fact, that a pick-up that has one frequency characteristic on one record material will have another frequency characteristic on another record material, depending upon the hardness. On these new instantaneous records, with fairly soft material, we have found it very annoying.

Also, as regards the high-frequency losses, a small playing diameter increases them very greatly, particularly with soft record material. That would seem to interfere with the control tone idea to some extent. We have measured losses at 10,000 cycles on nitrate lacquer amounting to some 28 db., playing from an 8-inch diameter to a 16-inch diameter. While that could be compensated for to some extent in recording, I wonder whether it would not make the control tone idea more complicated.

MR. MACNAIR: This discussion may have given the impression that correcting distortion of this type is very complicated. Many of you do something similar in the motion picture business every day. If the harmonic content of a variable-density negative is analyzed, harmonics and cross-modulation products will be found in abundance. These are eliminated by the simple process of printing, and certainly we do not claim to print 40,000 cycles very well. There are two ways of looking at these problems. The analysis into harmonic components is the more appropriate one for some problems, and the simple consideration of returning the wave shape to its original is another way of looking at it.

The micromatics of harmonic analysis for this problem leads to great complica-

tion, and it happens that the other way of looking at it is the simple way.

MR. PIERCE: Mr. Davee's remarks point out admirably the fact that our established amplitudes of cut, frequency response, record speed, stylus tip radius, and so on, are all so interrelated as to give a pleasing result. The types of distortion with which we are particularly concerned here are most readily observable when standard commercial records are played through a really high-fidelity system. In case Mr. Davee is really anxious to observe the distortions, we suggest that he try listening only to the frequency band between 5000 and 10,000 or 12,000 cycles.

I think that Mr. Kellogg has answered Mr. MacNair more aptly than I was able to do. The effect of compensating by properly poled dubbing seems to put the system in push-pull with the pull appearing as a separate episode from the push. It is obvious that this is a difficult technic to handle and it is hard to see how the final result can be better than it is in the case where we have a truly push-pull system. We are under the impression that this poled dubbing technic is not used as standard practice, so that many vertical-cut records are released without its advantages. Mr. Kellogg's concluding remarks about the inadequacy of geometrical analysis seems to be effectively answered by the data exhibited in our Fig. 9. It is true that other factors may become important unless the reproducer meets the requirements we have discussed in the paper.

The condition that troubles Mr. Hasbrouck has been chosen deliberately, and the illustration to which he refers is a fairly accurate representation of the geometrical conditions obtaining in our equipment. As we have explained, this is done to prevent distortion due to "rattling" of the stylus; in other words, to provide positive drive for the stylus which is following a laterally modulated groove. It is true that the pressures at the points of contact are greater than they would be if the stylus rested in the bottom of the groove, but it is possible to build a reproducer that will not deform the record material even when such a condition exists. As we have pointed out, this is necessary in order to permit us to calculate distortion. We believe that the distortion so calculated will be at least no greater than that caused by allowing the needle tip to trace a random course that we can not examine analytically. The necessary requirement in this case is that the stylus must execute a vertical motion without generating a corresponding electrical output.

We have been able to show experimentally that instantaneous cold flow of the record material is not an important factor when a sufficiently light reproducer is used. A simple and adequate way of checking this fact is by making a frequency-response record and playing it at more than one speed, such at an $33^1/_3$ and 78 rpm. When the record speed is varied in this way the output at all corresponding frequencies should change by a constant factor. When this is the case it indicates that the reproducer stylus is not deforming the record material either temporarily or permanently.

Variations in hardness of the record material can affect the frequency characteristic only because many cutting heads depend upon the record material for at least part of their damping. Thus the amplitude of the cut is a function of frequency, record hardness, and linear groove speed, instead of frequency alone. In the best cutting heads, this effect is practically negligible. As we have shown in the paper, any variation in frequency response over the record surface is an indica-

tion either of a poor cutting head or of too great cutting levels. Variations in amplitude upon playback, of 28 db., corresponding to only a 2:1 variation in linear groove speed seem startling to us and are a strong indication of some serious condition that should be corrected.

Mr. MacNair's final argument is beautifully expressed and seems plausible but will not bear close inspection. Regardless of the argument used, it is impossible to change the physical fact that transmission of the complete band corresponding to the original poids, that is, all high harmonics and cross-modulation products, is so difficult as to be practically impossible. Mr. MacNair will agree, I am sure, that, if we can reproduce only a difference tone because the sum of two high frequencies lies outside the transmission band, it is impossible to restore the original two tones by his poled dubbing technic without leaving distortion in the final product. We realize that correction of this sort for vertically cut records is decidedly beneficial and may even, if properly executed, produce a final result comparable to that which is easily obtained with lateral groove modulation. Although the technic has certain apparent disadvantages, we regret that it is not used more consistently in commercial practice.

A HIGHER-EFFICIENCY CONDENSING SYSTEM FOR PICTURE PROJECTORS*

F. E. CARLSON**

Summary.—*In motion picture projection optical systems for tungsten-filament sources, the condenser design is such that the source is imaged well ahead of the picture aperture. This position is dictated by considerations of uniformity of screen brightness. It is not the optimal position from the standpoint of utilization of light, for it entails losses at the aperture. At the best position for efficiency, the degree of brightness uniformity is inacceptable because of the non-uniform brightness of the source. The paper describes a method for reducing such losses without sacrificing picture quality.*

The design requirements of optical systems for picture projection have been well defined in technical papers presented before the Society over the years. It is well known, for example, that to achieve uniformity of lighting of the screen the condenser diameter and condenser-aperture spacing must be such that upon looking backward through the projection system from all points on the screen one will see equal areas of uniform brightness. In practice that is not completely realized at the margins because of vignetting by the projection lens tube.

Given a source of uniform brightness, uniform illumination of the screen is achieved with greatest efficiency in light utilization if the image of the source formed by the condensing lens lies slightly ahead of the aperture. When, as in Fig. 1 (*A*), the image is formed at the aperture, the light lost at this gate is at a minimum. However, the divergence of the beam is then so great that much of the light is not intercepted and transmitted by the projection lens. As the source image is moved farther ahead, Fig. 1 (*B*), aperture losses increase but a greater proportion of the remaining light is transmitted by the projection lens. It is apparent that for any given combination of condenser-aperture spacing, aperture size, and projection lens, there is an optimal position where the sum of the two losses is at a minimum.

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 15, 1938.

** General Electric Co., Cleveland, Ohio.

If the source be non-uniform in brightness, the image formed by the condensing lens will also be non-uniform. It is the degree of uniformity across the beam at the picture aperture that determines whether the screen is acceptably illuminated; and this uniformity increases as the position of the image is moved forward from the aperture. In practice the image has, accordingly, been placed a considerable distance from the point of optimal utilization of light. This paper deals with means for minimizing the losses that have heretofore been thus incurred.

In order to determine the effect of image position upon net output of projectors, tests were made with five typical optical systems of

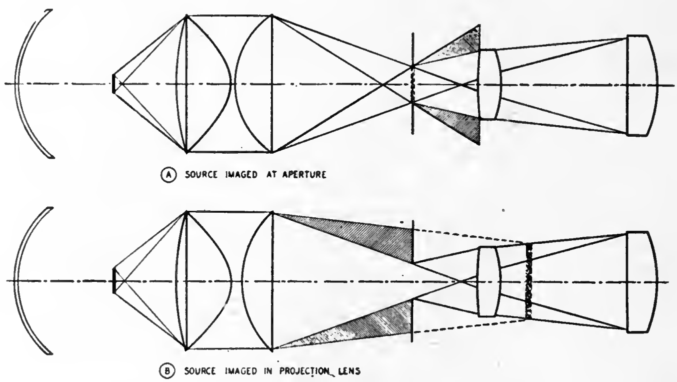


FIG. 1. Effect of position of source image upon light losses at picture aperture and at projection lens.

the 16-mm. size. The condensers employed included the usual spheric types as well as aspheric combinations. The light-source was an incandescent filament lamp of the conventional biplane construction, and of such size as to insure that the system was always completely filled.

Various image positions along the optical axis were attained by changing the focal length of the condensers. In the case of the spheric combinations, and in the aspheric systems combining all corrections in one lens, this was accomplished simply by substitution in the element nearest the aperture. In one system, in which both elements are aspheric, the focal length of the combination was changed by introducing a third element of appropriate focal length mounted close to the lens nearest the aperture.

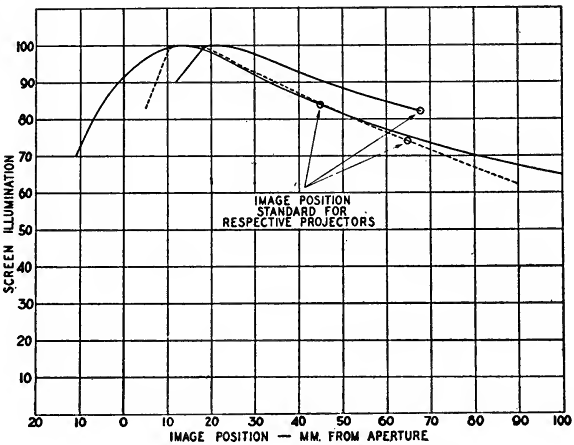


FIG. 2. Relation of position of source image to screen illumination for 16-mm. projection systems with aspheric condensers.

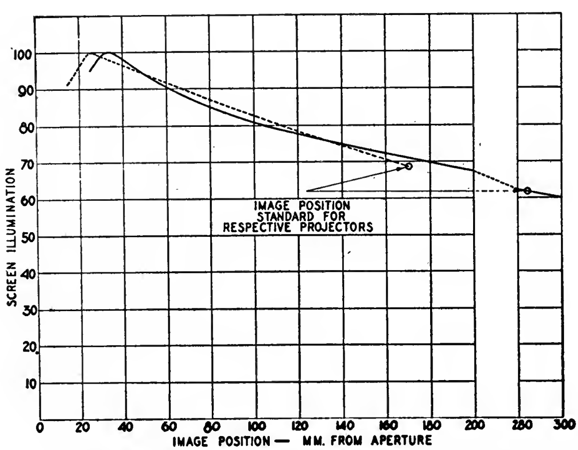
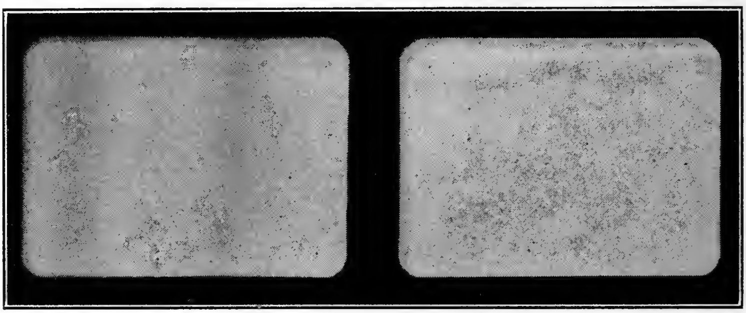


FIG. 3. Relation of position of source image to level of screen illumination for 16-mm. projection systems with spheric condensers.

The results of these tests are shown graphically in Figs. 2 and 3. While the data apply only to the five optical systems tested, they indicate the order of the penalty imposed by non-uniformity of source in projectors generally, whether of the 8-mm., 16-mm., or 35-mm. size. The standard position of the source image for each of the equipments tested is noted on the curves. It will be observed that in the aspheric systems the net output actually utilized is 16 to 25 per cent below the maximum possible, and that for spheric condensers it runs to nearly 40 per cent below.

Fig. 4 shows, in A and B, respectively, the approximate appearance of the screen when the image is focused at the point of maximum



(A) (B)

FIG. 4. Appearance of screen when source is imaged (A) at point of maximum light output, and (B) at standard positions indicated in Figs. 2 and 3.

light output and at the positions actually used in practice. It will be seen that the lack of uniformity is evidenced crosswise of the screen, not vertically. In other words, so far as uniformity of brightness from top to bottom of screen is concerned, the source could be imaged close to the position of maximum output.

It has been standard practice to focus both dimensions of the source in the same plane. It is not necessary that that be done. A more rational procedure would be to incorporate a cylindrical or toric surface in the condensing system to provide a differential in the distance at which the vertical and horizontal dimensions of the source are focused. Such structures are commercially feasible. Cylindrical surfaces have, for example, been used to give the beam from a circular source an approximately elliptical cross-section in order to fit it more nearly to the dimensions of a particular aperture. If, now,

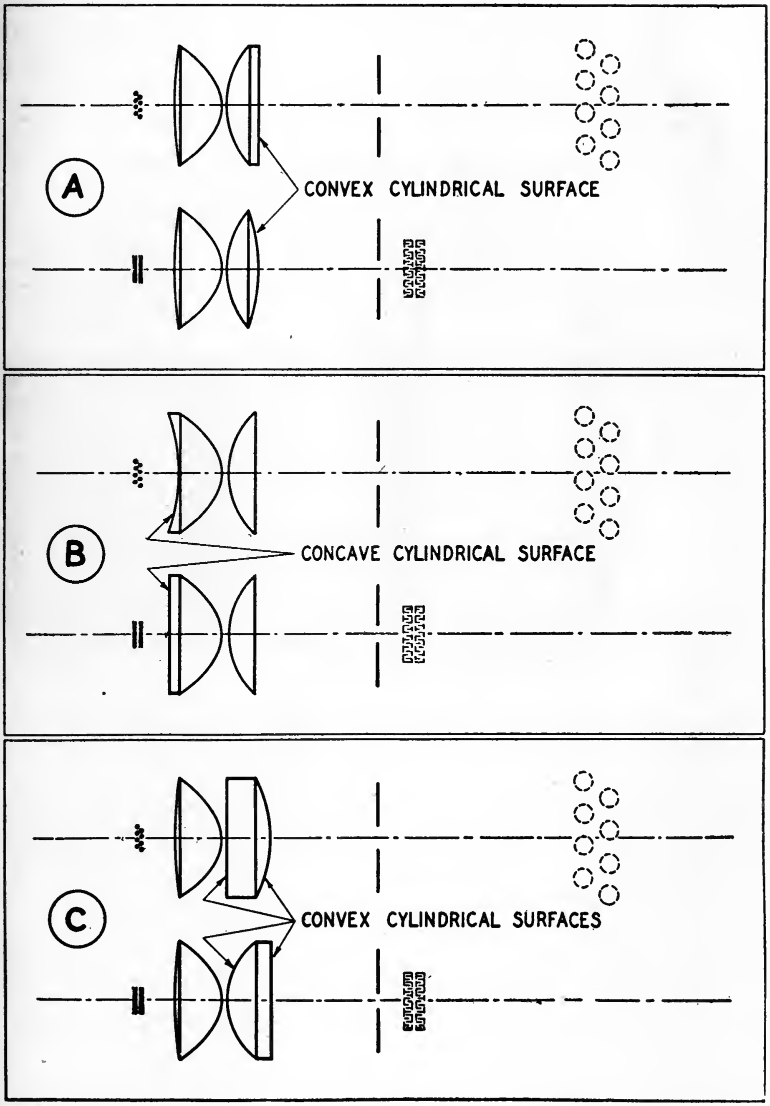


FIG. 5. A few of the methods available for incorporating cylindrical or toric surfaces in typical condensing systems for differential focusing of width and height of source.

the structure is instead adapted to focus one dimension of a rectangular source in the plane of maximum output and the other dimension in the nearest plane for which uniform illumination results at the aperture, considerable gain in output can be achieved at the same time that uniformity of screen brightness is preserved.

Fig. 5 illustrates three of a number of possible modifications of representative types of condensing systems to accomplish the differ-

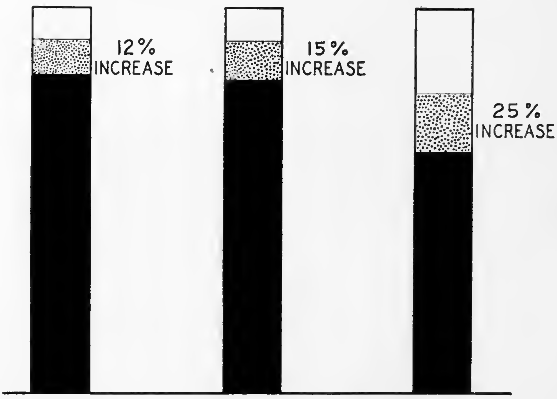


FIG. 6. Increase in light output obtained by incorporating cylindrical or toric surface in condenser.

The height of the column represents, for each of three equipments, the net light output with source imaged at position for maximum light utilization, disregarding uniformity of screen. The black portion represents the part of the possible output realized in equipment as now made. The shaded blocks show the gain when condensers are modified as described.

The three columns are not to the same scale and therefore are not to be compared with each other as to absolute values.

ential focusing. *A* shows the simple case of substituting a cylindrical for a plane surface of a combination, thus producing a lens of shorter focal length in the meridian corresponding to the length of the coils of the lamp. In *B* the cylinder is concave instead of convex in order to increase the focal length of the meridian corresponding to the position at right angles to the coils of the lamp. If all the surfaces of the combination were spheric or aspheric one would provide, in place of the cylindrical surfaces illustrated, corresponding convex and concave toric surfaces. In *C*, two cylindrical (or toric) surfaces

with their axes 90 degrees to each other are used to produce a differential in strength or focal length in these two meridians.

Lenses were made incorporating these principles, but otherwise identical with those employed in the above tests of conventional systems. They were tested in three of the equipments, all representative of the high-quality group of 16-mm. projectors, with results as charted in Fig. 6. The increase in net output of the projectors varied from a minimum of 12 per cent for an aspheric, to 25 per cent for a spheric system. Factors affecting the realizable gain in efficiency include the angle of acceptance and the relative aperture and focal length of the projection lens, as well as the condenser-aperture spacing.

DISCUSSION

MR. KELLOGG: Your analysis and estimate of gain are based upon the supposition that you have a large enough projection lens to collect all the light that gets through the aperture; in other words, that you fill the lens with the filament image at all times?

MR. CARLSON: The gains shown are measurements and not estimated values, and there has been no change in any of the optical systems other than in the focal length of the condensing lens. That is, the projection lens was not changed nor was its position changed.

I doubt that projection lenses, even when used with condensing systems designed in accordance with present practice, collect and redirect to the screen all the light that gets through the aperture. Ignoring surface losses, there is usually some obstruction to marginal rays, varying in amount with the angle these rays bear to the optical axis. The reason we obtain a gain in screen illumination is that we are working at the point where the sum of the losses at the projection lens and at the aperture is reduced.

MR. KELLOGG: Would not your story be changed if you assumed a smaller projection lens? You are assuming, are you not, about as fast a projection lens as is practically available?

MR. CARLSON: Not necessarily. The data for each optical system tested were not included in the charts shown, but there were also tested in the course of the earlier experiments optical systems incorporating $f/2$ projection lenses instead of $f/1.65$, and the same relative gains seem to apply.

A COLOR DENSITOMETER FOR SUBTRACTIVE PROCESSES*

R. M. EVANS**

Summary.—*In subtractive color processes it is desirable to have some type of sensitometry to tell how the process departs from correct rendering of neutral gray scales. Reading the density of a color deposit through an arbitrary filter does not give rise to a useful value in terms of the final color process. For practical use the "effective density" of a color is defined as the visual density produced by adding sufficient of the other colors of the process to produce gray. An instrument is described that reads such values directly. This instrument is capable also of analyzing the amounts of each of two or more colors when present simultaneously and permits the analysis of a sensitometric exposure into the corresponding deposits of each color. Complete sensitometric curves may be drawn for all the records from the readings of a single strip.*

In all processes of subtractive color photography, the problem of so "balancing" the individual color records that the requirements of best tone reproduction are realized is rather difficult. A large part of the difficulty arises from the lack of suitable means for measuring and specifying the actual amounts of image-forming material in each record individually. Once these amounts are measured, however, there still remains the problem of determining the relationships between them that will produce the required results.

The conventional methods of colorimetry may always be applied to any color process, either for each layer or for the process as a whole. Such methods, however, are concerned primarily with the later stages in which the final colors may be compared to the original subject. For this purpose, no substitute is known or needed and the subject need not here be discussed further.

In the earlier stages when any color process is being worked out or being brought under control, there usually exists a need for the equivalent in colors of black-and-white sensitometry. It is a usually accepted axiom of color photography that the colors used and the

*Received June 6, 1938. Communication No. *676* from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

mode of operation of any process must make it possible to reproduce a scale of neutral grays as such, unless a fourth record in gray is to be added to the image. Even in this case a close approximation to this condition is necessary.

The methods of sensitometry apply directly to such a gray scale and the reproduction of such a scale is usually considered to define the tone or brightness reproduction possibilities of the process. In other words, the brightness reproduction scale of the process is assumed to be defined by the brightness reproduction of a scale of neutral grays. In reality, such an assumption is not justified for any part of the reproduction except that of gray scales, and it obviously has nothing to say about the reproduction of hue or saturation of colors. That that is true is obvious from the fact that three colors that are each very similar to gray might be used and the reproduction of a scale of grays made practically perfect without aiming at a color process worthy of the name.

The present paper is concerned with subtractive color processes in which the individual colors used for the part images are considered satisfactory in themselves. Consideration will be given only to the measurement of each color record in such a way that it is directly apparent how much of each is necessary to form a gray of the required density.

The statement is found frequently in the literature of color photography that one of the important requirements of a subtractive color process is that the contrast or "gamma" of all the color records shall be the same. In general principle, this requirement is obvious enough, but further consideration shows that it is a rather vague concept unless new definitions are made for density and gamma.

In the sensitometry of ordinary silver processes in which the images are essentially gray, the term "density" is defined as the logarithm of the reciprocal of the transmissions of the deposit. It is usually assumed that the transmission is measured visually, but that is not entirely necessary since the deposit is usually so uniform in its transmission of light of all colors that the sensitivity of the eye to color does not come into the problem as a large variable. "Gamma" is then defined as the slope of the line in a plot of density against the logarithm of the exposure that caused it. In other words, it is the ratio of cause to effect, and as such is an extremely useful concept. The requirement stated above for color processes, then, is that the ratio of cause to effect shall be the same for each color record.

The three colors are assumed, whether correctly or not, to give gray when present in equal amounts. This latter assumption is not true in the case of most practical processes. What is wanted, then, is a method of measuring the color deposits constituting each color record, in such a way that the quantity of each color *appears* equal when the colors superimposed give a visual gray. If each record could be read in terms of "density," then, when the density of each of the color records was the same, the result of superimposing the colors would be gray. The "gamma" of each record, defined in terms of these densities, would then each be the same when the process was reproducing a gray scale. This result may be accomplished by defining a new kind of density which might be called the "equivalent density"

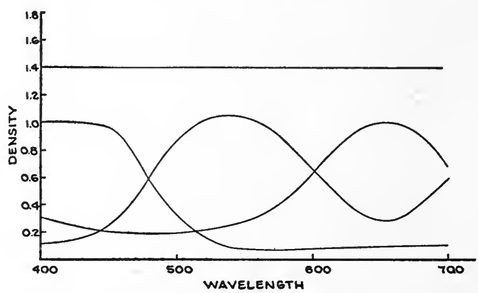


FIG. 1. Effect of impurities upon combined density.

of a color. We may define this as follows: *The "equivalent density" of a color in any subtractive color process is the visual density it would have if it were converted to a neutral gray by superimposing the just-required amounts of the fundamental colors of the process.* The definition appears as if it might be extended to any color independent of a color process and defined as the density that a color would have if it were subtractively combined with its exact physical complementary. Such an extension of the definition, however, does not lead to the same result. This may be demonstrated by an example.

If three practical dyes are chosen which in a certain ratio give neutral gray, the visual density of this gray is greater than the maximum absorption density of any one of the dyes at any wavelength. This is due to the so-called "impurity" of the colors, and is illustrated by the arbitrarily drawn curves of Fig 1. In this figure the density of each dye at each wavelength of light in the spectrum is plotted

separately, the density at each wavelength being defined as in the case of silver images. (This is possible because the relative sensitivity of the eye to *different* wavelengths does not enter.) The density at each wavelength for the three dyes combined may then be obtained by adding the three curves at each wavelength, just as neutral densities may be added. Since the three dyes have been chosen to give a neutral gray when mixed, the point-by-point addition of the curves gives rise to a fourth curve which is at essentially the same density at all wavelengths. Being the same at all wavelengths, this density is the value that would be read by white light on a densitometer. Note, however, that since each of the dyes had a definite density at *every* wavelength, the final neutral density is higher than any point in any of the curves. If the *exact* physical complementary for any of the dyes were added to that dye, nothing would have been added to its *maximum* density and the final neutral density would have been less in such a case than in the case of the three actual dyes.

Furthermore, the term "complementary" color as used here could apply only to a given dye at a given concentration, and would require to be changed if the concentration of the dye in question were changed. It is for these reasons that the density of a dye deposit as determined by reading it through an arbitrary filter on a visual densitometer does not lead to density readings that are directly significant for a process in which the dye is used.

It is apparent from what has been said above that the density curve for any individual color record in a subtractive process may be obtained readily by determining the densities formed when sufficient amounts of the other two colors are superimposed on each step to form a neutral gray. The densities so determined have the property that when equal densities of all the colors are superimposed the result is a neutral gray whose density is equal to that of each record. In other words, if the densities are so determined, the sensitometric curves for each record must have the same slope or gamma and must lie in the same position with respect to the exposure axis in order that the process shall reproduce a scale of neutrals as a scale of neutrals.

A simple instrument has been devised for the purpose of measuring densities according to the above definition. In principle it is similar to that of the Capstaff-Purdy densitometer[1] now widely used in the motion picture industry. In this well known instrument the image whose density it is desired to determine is placed in a beam of light

in series with a circular neutral gray wedge whose densities are known at every point. By another path, light from the same source is brought around the wedge and both beams of light enter an eyepiece in such a way that comparison of the brightnesses of the two may be made to high precision. The brightness of the unimpeded beam, due to the length of its path, is made less than that of the wedge beam in

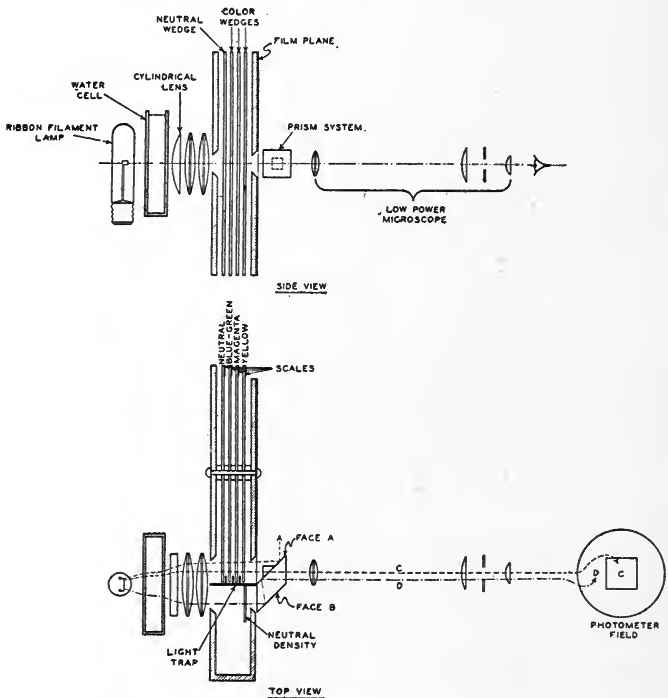


FIG. 2. Schematic arrangement of color densitometer.

a known ratio. In other words, it requires a definite density of, say, 3.4 in the path of the light through the wedge to make it equal to brightness of the comparison beam. The density of the unknown sample may be determined by moving the wedge until the two beams match. At this point it is known that the sum of the density of the wedge and the unknown equals 3.4, and the instrument may be calibrated to read the difference between this and the actual wedge density, or the density of the unknown. The great advantage of this

type of instrument, aside from its simplicity, lies in the fact that the actual brightness of the field when the two beams are matched is always the same.

The present instrument retains this feature and has, as well, the important feature for visual color work that both fields are neutral at the balance point.

The design of the instrument is as follows: In a densitometer with an optical system similar to that of the Capstaff-Purdy instrument there is placed in the beam of light passing through the wedge a color wedge for *each* color of the process *formed by the color process* for which the instrument is to be used. If it is a three-color process there will be three color wedges in addition to the gray wedge of the usual instrument. Fig. 2 shows the instrument diagrammatically.

To measure the density of a color deposit the film carrying the color is placed in the beam C with all wedges set at maximum transmission. The brightnesses of the two halves of the field are then roughly matched by rotating the neutral wedge. Considering for the moment that the color being measured is that of one of the color records only, each of the *other* two wedges is rotated until the transmitted light is gray. The brightnesses of the two halves of the field are then matched and the exact density is then read from the scale of the neutral wedge. In actual practice the balancing operation is only slightly more difficult than in the case of the single-wedge instruments.

If the color is not a deposit of one color record alone but is a mixture of two or of all the records, the density may still be determined and is of equal validity to that read from a deposit of a single color if care is taken to add in only those colors in which the original is deficient. Where the density corresponding to one color record is all that is desired there is no need for calibration of any of the color wedges. It is within the capacities of the instrument, however, to calibrate itself, and when this is done it becomes possible to determine the equivalent density of *each of the colors in any mixture.* This makes it possible to determine the curves for each color record from a single photograph of a neutral scale or, more conveniently, from a single exposure to white light in a sensitometer of the conventional type.

The calibration and application of the instrument for this purpose are carried out as follows: Arbitrary scales are attached to each of the color wedges. If wedge C is to be calibrated, it is set at the first division of its arbitrary scale, say, ten degrees from the point at which

the wedge has no color. The other two wedges are then rotated until the light passing through is gray, the brightness of the beam is matched to that of the comparison beam, and the "equivalent density" read from the neutral wedge is applied to the wedge being measured. In other words, each wedge at successive points is considered as a sample to be measured, and in this way each is calibrated.

Any color may now be specified in terms of the equivalent densities of each of its components. To do this the sample is placed in the beam as usual; the wedge corresponding in color to the predominant color of the sample is left at zero, and sufficient of each of the other

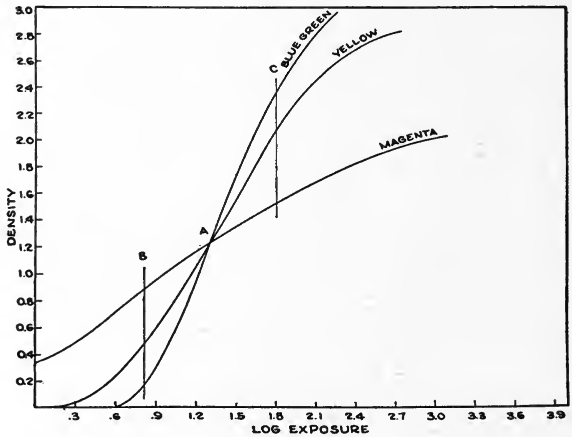


FIG. 3. Color density curves of a sensitometric strip.

colors is added by means of the wedges to give a neutral which is then balanced with the neutral wedge. The neutral wedge now reads the equivalent density of the color present in the greatest amount, and the densities on the other two wedges, subtracted from this value, give the equivalent density of each of the other colors present in the sample.

If a sensitometer strip is exposed by white light and the resulting steps are read on the instrument, the curves of each color may be plotted independently. Such curves, read on an instrument built according to the above scheme are shown in Fig. 3. They are chosen deliberately to show a color process *not* balanced for reproduction in gray of a neutral scale. The strip appeared neutral on step A, red at step B, and green at step C.

A slight modification of the instrument may be necessary in the case of some processes, particularly if the deposits for each color are highly diffusing. In this case the addition of spherical lenses between the color wedges as shown in Fig. 2 may be necessary. In any case the addition of such lenses will increase the light transmission of the instrument. The instrument depends for its successful operation, particularly if the color wedges are to be calibrated, upon the interchangeability of any color at the wedge and at the position of the sample. This is readily tested by reading a series of color deposits separately and then superimposed. An actual instrument built in the Kodak Research Laboratories for a process employing dye images has been highly successful and meets the requirement of additivity well within the required precision. Finally, it must be emphasized that such an instrument must be fitted to each particular process, the wedges being made by the process, and the interchangeability of colors at the wedge and sample positions must be checked over a sufficient range before the results can be expected to yield useful information in the control and adjustment of the process.

The author acknowledges his thanks to his colleagues, Mr. George Silberstein and Dr. W. T. Hanson, Jr., the former for his painstaking construction of the first instrument and the latter for the additivity test necessary to determine the reliability of the instrument.

REFERENCE

[1] CAPSTAFF, J. G., AND PURDY, R. A.: "A Compact Motion Picture Densitometer," *Trans. Soc. Mot. Pict. Eng.*, **XI** (1927), No. 31, p. 607.

REPORT OF THE PAPERS COMMITTEE*

Summary.—*The plan of work followed by the Papers Committee during the past couple of years is discussed, together with the results achieved by following the plan. The Report concludes with regulations of the Society with regard to the preparation of papers for presentation and publication, and detailed instructions concerning editorial style and typographical arrangement.*

The functions of the Papers Committee are two-fold: (*1*) to arrange and supervise an appropriate program of papers for our semi-annual meetings; (*2*) to secure an adequate number of papers to fill twelve issues of our JOURNAL during each year. Nearly 1400 members depend upon the Committee for the latter function; about 250 for the former.

There were 96 papers and 13 reports published in the JOURNAL during 1937. Out of this total of 109, only 8 were submitted directly to the Editorial Board for publication; 5 were reprinted from other publications, and 1 was read before a Local Section meeting. These 14 papers represent less than 13 per cent of the total, and should impress upon us the importance of having an adequate number of papers at each semi-annual meeting to provide material for six issues of the JOURNAL. It indicates also that the majority of our membership are stimulated primarily to write papers when they plan to attend Conventions and not at other times.

Two years ago, a plan was suggested by this Committee for the organization of its work. It consisted of the following steps: (*1*) publication of a request for papers in each issue of the JOURNAL for four months before the meeting, offering preferred positions on the program, with ample time for presentation and discussion, to those who turn in their manuscripts six weeks before the meeting; (*2*) personal solicitation of papers by members of the Committee; (*3*) publication of abstracts in the issue of the JOURNAL appearing immediately before the meeting; (*4*) request for manuscript copies 10 days before the meeting. It has, in addition, been customary to circulate a Tentative Program about 3 weeks before the meeting as well

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received May 25, 1938.

as to publish this Program in the number of the JOURNAL immediately preceding the meeting.

This plan has proved quite effective, as shown by the quality and number of papers presented at the last four meetings. Much work is necessary, however, to secure abstracts and manuscripts on time, but authors appear to have become more appreciative of the requirements and are making greater efforts to comply with the regulations. Some lack of understanding of the meaning of the term *abstract* has been found among a few authors; others have said that it was unfair to request manuscript delivery before the meeting.

An "abstract" may be defined as a *digest* of a paper, which states in clear, concise sentences the significant material discussed in the paper. Examples of good abstracts are included in the Special Bulletin of this Committee, supplementing this report. This Bulletin was drawn up two years ago and has been revised from time to time. It contains a summary of the administrative practices of the Society regarding acceptance and preparation and oral delivery of manuscripts. It has been distributed to the majority of authors during the past two years and has proved of service to the authors as well as the editorial office. Several papers are received for each meeting, however, that do not comply with our regulations, and it is evident that the authors have not read or, perhaps, have not been aware, of the regulations, especially those related to bibliography and footnote style, illustrations, and drawings. It is suggested, therefore, that wider distribution should be made of this Bulletin by publishing it in the JOURNAL as a supplement to this report. Reprints could then be obtained for circulation to authors who are not members of the Society.

It has been customary to print the Preliminary Program both in the JOURNAL issued before the meeting and in leaflet form for distribution to all members and authors. A final, corrected program is also printed in the JOURNAL a month after the meeting. It seemed an unnecessary duplication to distribute the Preliminary Program twice, and with the approval of the Board of Governors, the Preliminary Program was omitted from the April, 1938, issue of the JOURNAL. Abstracts have been published, however, to facilitate discussion at the meeting and to provide a source of reference until the paper has been published.

It is important that the Papers Committee should coöperate closely with the Publicity Committee, especially during the period just prior to and during the semi-annual meetings. Copies of all abstracts of

papers are turned over to the Publicity Committee several weeks before the meeting, as well as details concerning special demonstrations or prominent speakers on our programs.

Two years ago we began the practice of supplying the Chairman of the Publicity Committee with a copy of all available manuscripts for his use during the period of the Convention. This plan proved very effective, but imposed a handicap upon the Committee because it had been customary to obtain only one copy of each author's manuscript, and occasionally it was necessary for both Committee Chairmen to refer to a manuscript simultaneously.

Accordingly, it was decided that our request for manuscripts before the meeting should specify two copies so that the Publicity Committee could have the exclusive use of one set. It is always possible, of course, for an author to make the reservation, when turning in his copies, that further corrections may be necessary on the manuscript and that the Committee is not to release the copy submitted, for publication in the JOURNAL, until these corrections are supplied. If the manuscript is essentially correct (even though some or all of the figures may be missing), it is usually satisfactory for publicity purposes.

A request for a finished manuscript 10 days before the meeting is not believed to be too severe, and past experience has shown that the majority of authors are able to meet these requirements satisfactorily.

It may be of interest, in conclusion, to present a rough classification of the information that has been presented to the membership at our last four meetings. Your comments and suggestions are requested. The number and type of papers may be divided broadly as follows:

Acoustics	4	Optics Lighting Projection	34
Apparatus	28	Sound	30
Color	9	Stereoscopy Stereophony	6
Education Historical Industrial	11	Television	3
General Engineering Practice	8		
Laboratory Photographic	28		

This summary indicates that emphasis has been placed about equally on papers dealing with apparatus, laboratory and photographic problems, optics, lighting, and projection. The papers on sound have dealt with many aspects of this subject, and the total

number of papers in the class is about the same as the total in each of the other classes. These figures show that no single subject of these fundamental classes has been emphasized at our meetings to the exclusion of others.

The usual effort has been made to obtain papers for the 1938 spring meeting. The results have been most encouraging. Approximately 69 papers have been offered and only 3 were withdrawn. There are 15 papers scheduled on the program, the authors of which will not be present. These will be restricted to 10 minutes or may be read by title if time is limited. There are 15 papers dealing with apparatus and these are limited to 10 minutes for presentation. A total of 36 papers remain, therefore, for which a longer reading time has been allowed.

It is particularly gratifying to note the number of papers on the program by technicians on the West Coast, and the Committee wishes to acknowledge the excellent coöperation shown by the Research Council of the Academy of Motion Picture Arts & Sciences in connection with the preparation of the program.

The generous response to our request for papers indicates that we may yet achieve the goal of every technical society—a *selected* papers program and a large enough volume of paper material to permit the editorial board to publish a *selected* group of high-quality papers in each number of our JOURNAL.

G. E. MATTHEWS, *Chairman*

P. ARNOLD	C. FLANNAGAN	F. H. RICHARDSON
L. N. BUSCH	E. W. KELLOGG	P. R. VON SCHROTT
A. A. COOK	R. F. MITCHELL	C. K. WILSON
L. J. J. DIDIEE		I. D. WRATTEN

(*West Coast*)

L. A. AICHOLTZ, *Chairman*

C. N. BATSEL	L. D. GRIGNON	H. C. SILENT
O. O. CECCARINI	W. A. MUELLER	H. G. TASKER

Supplement

REGULATIONS OF THE SOCIETY OF MOTION PICTURE ENGINEERS RELATED TO THE PREPARATION OF PAPERS FOR PRESENTATION AND PUBLICATION

This bulletin contains details regarding the preparation of material for papers, both for presentation and for publication, and also includes information on the Administrative Practices of this Society relative to the responsibility it assumes regarding the acceptance of papers for publication. Please read the information carefully.

Sect. 8, Div. 4 Administrative Practices reads as follows:

Instructions to Authors.—Papers may be submitted for presentation at the Semi-Annual Conventions, for publication in the JOURNAL of the Society without presentation at Conventions, or for presentation at Local Section meetings.

Papers will not be accepted for presentation at Semi-Annual Conventions unless their quality is regarded by the Board of Editors to be such as to merit publication. In many cases, however, it is impossible for the authors to submit manuscripts sufficiently in advance of a Semi-Annual Convention to permit careful examination by the Board of Editors. The Board of Editors, therefore, shall reserve the right to decline to publish any paper not submitted at least one month prior to a Semi-Annual Convention and approved, even though it be accepted by the Papers Committee of the Society and presented at a Semi-Annual Convention. Papers presented at Local Section meetings are subject to these same regulations.

Papers accepted for publication but not presented at Conventions or other Society meetings will be published as early as possible, but do not have priority over those already in the hands of the Editorial Staff.

The subject matter of papers should be such as to be of interest to the motion picture engineer, the term "engineer" being regarded in a very broad sense as "anyone who contributes to the building of the motion picture."

Prior Right of Publication.—Papers presented at Conventions or other meetings of the Society or submitted only for publication in the JOURNAL shall be regarded as the confidential property of the Society unless withdrawn by the author, and shall not be published elsewhere (except upon the approval of the Editorial Vice-President) until they have either been published in the JOURNAL or have been returned to the author. Prior publication to the extent of 30 per cent of the verbal length of any paper, with due acknowledgment of the source, is permitted.

Right to Reprint.—After its date of appearance in the JOURNAL, an article may be published in other publications provided complete credit is given to the JOURNAL of the Society of Motion Picture Engineers and to the author of the article in question. The citation should appear preferably after the title of the article or as a footnote to the article on the first page and should read as follows: *Reprinted from Journal of the Society of Motion Picture Engineers, Volume, Page, Month, Year.*

Prior Publicity of Convention Papers.—Publicity incident to the presentation of papers at conventions is the responsibility of the Papers and Publicity Committees of the Society and should not be undertaken by the authors or their representatives, except in collaboration with these Committees.

An abstract or abridgment for publicity purposes about 200 words long should be supplied about six weeks before the meeting at which the paper is to be read. Examples of satisfactory abstracts are the following:

"High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus"; W. Herriott, *Bell Telephone Laboratories, Inc.*, New York, N. Y.

High-speed motion pictures are employed at Bell Telephone Laboratories as a visual aid in the study of problems associated with the design, manufacture, and testing of telephone apparatus. A new high-speed camera of the optical compensator type operating at 4000 pictures per second is described, and its application to the study of problems associated with telephone apparatus is discussed.

"A Modern Motion Picture Laboratory"; C. L. Lootens, *Republic Productions, Inc.*, North Hollywood, Calif.

A complete description of the new laboratory of the Consolidated Film Industries, Inc., which was completed during the winter 1936–37. Included are layouts and pictures of equipment in the basement, first, and second floors. The description of the laboratory and equipment follows the sequence of operation of negative development, "dailies," master and release printing, together with a description of the special printers, processing units, chemical system, silver recovery system, and other mechanical items of interest.

"Reduction of Loop-Length Variations in Non-Slip Printers"; E. W. Kellogg, *RCA Manufacturing Co., Inc.*, Camden, N. J.

Compensation for varying degrees of film shrinkage is accomplished in the Bedford non-slip printer by changes in the length of a loop of film between a sprocket and the printing point. This involves uncertainty of synchronism by the amount that the loop, as first threaded, differs in length from the final running loop. For most purposes, the present designs do not cause more change in loop-length than may readily be tolerated.

For certain purposes, especially if this type of printer is to be employed for 16-mm. films, there may be too much departure for synchronism. A guide-roller arrangement is described by which the necessary change of angle of approach of the raw stock to the printing point is attained with comparatively small change in loop-length.

Several possible arrangements are considered and some other features of the non-slip printer are discussed.

Order of Publication.—The order of publication of material presented at conventions or submitted only for publication in the JOURNAL is at the discretion of the Board of Editors and is determined in general by the chronological order in which the papers are received, the timeliness of the material, the technical quality of the papers, and their editorial completeness. The Board of Editors will give due and proper consideration to requests for special and early publication.

The Complete Manuscript.—The complete manuscript, from the editorial point of view, consists of the following items:

(*a*) Title.
(*b*) Name of author.
(*c*) Company affiliation (as a footnote on the first page).
(*d*) Summary of paper (not to exceed 500 words).
(*e*) The paper proper.
(*f*) A complete list of references or citations.
(*g*) A complete set of illustrations suitable for making engravings, with a caption for each illustration.

Text.—Papers should be typewritten, double spaced, upon only one side of the paper. It is desirable to send for publication the original (ribbon copy)—a carbon copy is easily erased and may become illegible.

Illustrations.—Each drawing or photograph should occupy a separate sheet and be capable of good reproduction. Blueprints, photostats, or sepia prints will not be accepted. Tracings or line-drawings should be made with black india ink

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The minimum amount of reading matter should be included upon the illustrations. Necessary information can better be set in type in the caption accompanying the illustration.

The maximum width of a JOURNAL cut is 4 inches and the maximum height is $6^1/_4$ inches. Illustrations or drawings should preferably be larger and not smaller than these size requirements. It is important that the necessary reduction of an illustration will not make the height of letters contained in reading matter on the

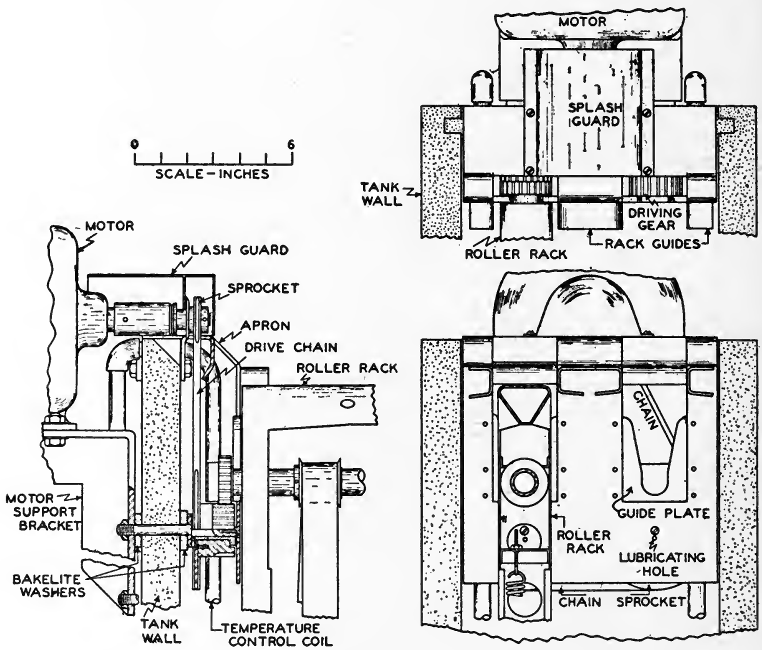

FIG. 1. Good example of a drawing.

illustration less than $^1/_{32}$ inch. All inscriptions on graphs or illustrations should be lettered and *not typewritten*.

When preparing illustrations, the style of lettering should be so chosen and the lettering so placed upon the illustrations as to be easily read when projected as lantern-slides before an audience of several hundred persons. Slides are usually reproduced about ten or more feet wide, and should be readable at a distance of fifty feet. Examples of satisfactory illustrations are shown in Figs. 1 and 2.

Listing Captions.—Captions for figures and tables should be listed upon separate sheets accompanying the manuscript.

Address.—It is important that the author's business affiliation and mailing address be written upon the first page of the manuscript.

PRINTING STYLE (HEADINGS)

The value and clarity of a paper are undoubtedly increased by dividing it into sections. The author can assist the editorial office by specifying the type of heading or sub-heading desired in each instance. The headings conforming to JOURNAL style, in descending order of importance, are as follows.

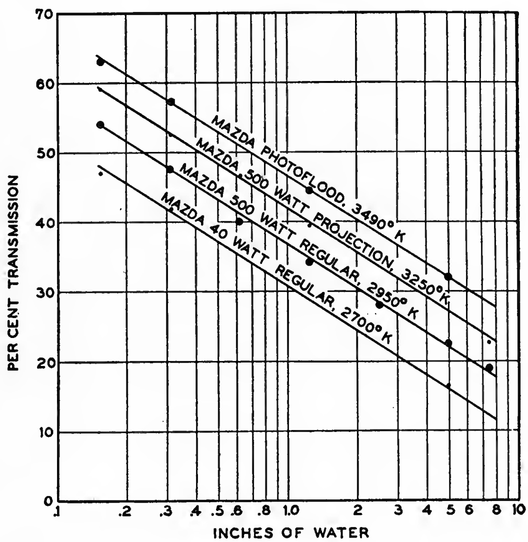

FIG. 2. Good example of a graph.

CENTERHEAD

Italic Centerhead

Italic Sidehead.—These sideheads are run into the text of the paragraph.

BIBLIOGRAPHY AND FOOTNOTES

References to literature should be accurate and complete. References to periodical literature should contain the following items in the given order:

(*1*) The reference number, corresponding to the number in the text.
(*2*) The name of the author of the paper; correctly spelled and with initials.
(*3*) The name of the article, in quotation marks.
(*4*) The name of the periodical (unless the periodical is well known its title should not be abbreviated).
(*5*) The volume number.
(*6*) The date, month, and year, in parentheses.

(7) The serial number, preceded by the abbreviation "No."
(8) The page number, preceded by the letter "p."

Example: [1] McCoy, J. L.: "A Light-Intensity Meter," *J. Soc. Mot. Pict. Eng.*, **XIV** (March, 1930), No. 3, p. 357.

Reference to books should be made as follows:
(1) Author's name.
(2) Name of book, in quotation marks.
(3) Edition.
(4) Publisher.
(5) Place of publication.
(6) Date of publication, in parentheses.
(7) Page, preceded by letter "p."

Example: Franklin, H. B.: "Sound Motion Pictures." 1st Ed. *Doubleday, Doran & Co.*, Garden City, L. I., N. Y. (1929), p. 101.

Reprints.—Reprints of articles published in the Journal may be obtained from the Society's headquarters office, Pennsylvania Hotel, New York, N. Y. These reprints are most economically obtainable currently with the publication of the issue of the Journal in which they appear. Prices in the quantity desired may be obtained by communicating with the Society's headquarters office.

REGULATIONS ON DELIVERY OF MANUSCRIPTS PRIOR TO A CONVENTION

(1) Two copies of each manuscript must be delivered to the Chairman of the Papers Committee at least one month before the meeting date in order that the paper be presented at the meeting. Papers arriving less than one month before the meeting date may, at the discretion of the Papers Committee, be scheduled on the program to be read by title or substituted for other papers in the event of cancellations.

(2) Two copies are needed in order that one set may be made available for the Publicity Committee and one for the Papers Committee during the period of the Convention.

(3) Final and complete copies ready for publication are desired. In the event that such are not possible, preliminary copies requiring further slight alterations in text or completion of illustrations (as per regulations regarding preparation for publication) before final release by the author will be accepted. These changes should be made, however, within one week after the meeting.

(4) Authors are urged to study carefully the regulations on the preparation of illustrations, and to give consideration to the legibility of the figures (1) as lantern-slides when the paper is read at the meeting, and (2) as printed cuts in the Journal.

SUGGESTIONS ON PAPER PRESENTATION AT THE CONVENTION

The attention of all authors is directed especially to the following suggestions regarding oral delivery of their papers at Conventions. Valuable time of the delegates and other authors will be conserved if each author on the program follows these suggestions:

(*1*) *Arrangement of Material.*—Manuscripts prepared for publication are seldom suitable for oral presentation. The paper should convey clearly to the hearer: (*a*) the purpose of the work; (*b*) the experimental method; (*c*) the results obtained; and (*d*) conclusions. The nature of the material and the time available for presentation will determine the degree of emphasis to be placed upon each subdivision. The author should make certain by trial against his watch that the essential points can be presented adequately in the time allotted to the paper.

(*2*) *Statement of Purpose.*—Orient the audience clearly as to the nature and purpose of the work. A lengthy historical review is generally out of place.

(*3*) *Technic.*—Describe the experimental method employed so as to indicate the principles involved. Omit details of apparatus or procedure unless there is some particularly novel development. Such data may belong in the published paper but will bore your audience.

(*4*) *Statement of Results.*—Present the results graphically, preferably with diagrams. Lantern-slides are more clearly seen than hand-drawn charts. These slides should be of standard size (3.25×4 inches) and should project clearly on the screen. Lettering should be kept to a minimum, consistent with clarity, and should be of such size that when the illustration is reduced for publication in the JOURNAL, the reduced lettering will not be smaller than $^1/_{32}$ inch in height. Usually it is not satisfactory to typewrite legends on drawings, especially if the typewriter type is small. Regardless of who has made the charts or slides, try them from the point of view of the audience before presenting them at the meeting. Do not read tables, a procedure that wastes time and destroys interest, but point out the general trend of the data. Whenever possible, the results of research should be shown by means of motion pictures, for which adequate projection facilities will be available.

(*5*) *Conclusions.*—Summarize the evidence and discuss the importance of the results or conclusions to the particular field of research involved.

(*6*) *Manner of Presentation.*—Do not read from a manuscript verbatim, unless the material has been written expressly for oral presentation. Talk directly to your audience in a clear, loud voice. Do not face blackboard or screen while speaking. Articulate distinctly.

(*7*) *Demonstrations.*—Details of demonstrations should be checked carefully before the opening of the session during which the demonstration is to be given. This will insure a smoother demonstration and avoid using up valuable time during the technical session.

Many exceptions to, and modifications of, the above suggestions will apply in particular instances. Nevertheless, general adherence to the points brought out will go far toward eliminating the valid criticisms that have been aimed at our programs.

Acknowledgment is made to the Society of American Bacteriologists and the American Chemical Society for many of the ideas incorporated in these suggestions.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Communications

18 (May, 1938), No. 5

Home Newspapers by Radio (pp. 7–9, 35)	F. C. Ehlert
General-Purpose Audio Amplifier (pp. 11–13, 26, 30)	A. Preisman
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International Photographer

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Zur Theorie des Rauschens (Ground-Noise Theory) (pp. 116–118) — A. NARATH

Das Farbfilmverfahren von Prof. Roux (Prof. Roux's Color-Film Process) (p. 119)

Das Problem des plastischen Tones im Film (Problem of Stereoscopic Effects on Film) (pp. 120–125) — C. BECKER

Bemerkungen zur Anwendung des Raumton-Effektes im Tonfilm (Remarks on the Use of Stereo-Sound Effects on Sound-Film) (pp. 125–126) — H. WARNCKE

Photographische Industrie

36 (May 4, 1938), No. 18

Neue Tonfilm-Kamera für 16-Mm. Schmalfilm (New 16-Mm. Sound Camera) (p. 537)

36 (May 25, 1938), No. 21

Die optischen Grundlagen für die Form des Linsenrasterfilms in der Farbenphotographie (Optical Basis for the Form of Lenticular Screens for Color Photography) (pp. 610–612) — A. KLUGHARDT

Proceedings of the Institute of Radio Engineers

26 (May, 1938), No. 5

The Fine Structure of Television Images (pp. 540–575) — H. A. WHEELER AND A. V. LOUGHREN

FALL, 1938, CONVENTION

DETROIT, MICHIGAN
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OCTOBER 31, NOVEMBER 1-2, INCLUSIVE

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Headquarters

The Headquarters of the Convention will be at the Hotel Statler, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, who are now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to SMPE delegates and friends, European plan, will be as follows:

One person, room and bath	\$3.00 to \$6.00
Two persons, room and bath	5.00 to 8.00
Two persons (twin beds), room and bath	5.50 to 9.00
Three persons, room and bath	7.50 to 10.50
Parlor suite and bath, for one	8.50 to 11.00
Parlor suite and bath, for two	12.00 to 14.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. Local railroad ticket agents should be consulted as regards train schedules, and rates to Detroit and return.

The following special rates have been arranged for SMPE delegates who motor to the Convention, at the National-Detroit Fireproof Garage (the Hotel Statler's official garage), Clifford and Elizabeth Streets, Detroit: Self-delivery and pick-up, 12 hours, \$0.60; 24 hours, \$1.00; Hotel-delivery and pick-up, 24 hours, \$1.25. Special weekly rates will be available.

Technical Sessions

An attractive and interesting program of technical papers and presentations is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the Large Banquet Room of the Hotel.

Registration and Information

Registration headquarters will be located at the entrance of the Large Banquet Room, where members of the Society and guests are expected to register and receive their badges and identification cards for admittance to the sessions and film

programs. These cards will be honored also at several motion picture theaters in the neighborhood of the Hotel, during the days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual Informal Luncheon will be held at noon of the opening day of the Convention, October 31st, in the *Michigan Room* of the Hotel. On the evening of Wednesday, November 2nd, the Semi-Annual Banquet of the Society will be held in the Grand Ballroom of the Hotel at 8 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Points of Interest

In addition to being a great industrial center, Detroit is also well known for the beauty of its parkways and buildings, and its many artistic and cultural activities. Among the important buildings that one may well visit are the Detroit Institute of Arts; the Detroit Historical Society Museum; the Russell A. Alger House, a branch of the Detroit Institute of Arts; the Cranbrook Institutions; the Shrine of the Little Flower; and the Penobscot Building.

At Greenfield Village, Dearborn, are grouped hundreds of interesting relics of early American life, and there also is located the Edison Institute, established by Henry Ford in memory of Thomas A. Edison.

On the way to Greenfield Village is the Ford Rotunda, a reception hall for visitors to the Ford Rouge Plant. Here are complete reproductions and displays of motorcar design, and representations of the famous highways of the world, from Roman days to modern, are on the grounds surrounding the building.

The General Motors Research Building and Laboratory, located on Milwaukee Avenue, will be of particular interest to engineers visiting the City.

Various trips may be taken from Detroit as a center—to Canada, by either the Ambassador Bridge or the Fleetway Tunnel; to Bloomfield Hills, a region of lakes; Canadian Lake Erie trip from Windsor, Ontario; to Flint, Michigan, another center of the automotive industry; to Milford, General Motors' Proving Grounds; and to the Thumb of Michigan Resort Beaches. The City contains also a number of beautiful parks and golf courses.

SOCIETY ANNOUNCEMENTS

STANDARD COMMITTEE

At a meeting of the Committee held on July 8th, the question of film cores was considered and tentative dimensions were proposed by Mr. P. Arnold, Chairman of the Sub-Committee dealing with the subject. Drawings are being prepared and a ballot of the Standards Committee will be taken very shortly.

Further study was given to the question of 35-mm. sound-track dimensions by the Sub-Committee under the Chairmanship of L. W. Davee, and J. A. Maurer reported for his Committee on Optical Reduction Ratio that a definite report and recommendation will be forthcoming at the next meeting, as soon as opinions have been received from all manufacturers and laboratories concerned with reduction printing.

The specifications for safety-film proposed by the French Standards Association for the meeting of Committee 36 of the ISA at Berlin during July were considered by the Committee. Final action on these specifications will be taken in the near future, as soon as the opinions of the Underwriters Laboratories have been obtained.

PROJECTION PRACTICE COMMITTEE

The last meeting of the season was held on June 23rd at the Paramount Building, New York, under the Chairmanship of Harry Rubin. Unfinished business was completed and preparations made for resuming the activities of the Committee in the fall, the date of the next meeting being scheduled for September 15th. In the meantime, several meetings of the Sub-Committees on Projection Room Plans, under the Chairmanship of S. Harris, and on Projector Tools and Tolerances, under the Chairmanship of P. Larsen, have been held, and it is expected that complete reports will be available from these Sub-Committees by the end of the summer.

The proposed revision of the NFPA "Regulations for Handling Nitrocellulose Film" has been completed and copies of the revision have been transmitted to a special committee established by the NFPA to consider it. It is expected that the revision will be in proper shape for publication in the fall. The SMPE is represented on the NFPA Committee by S. Harris, Chairman of the Sub-Committee on Projection Room Fire Regulations, of the Projection Practice Committee.

PACIFIC COAST SECTION

At a meeting of the Pacific Coast Section held at the Filmarte Theater in Hollywood on June 29th, two papers presented at the Washington Convention last May were re-presented, namely, "The Transmission of Motion Pictures over a Coaxial Cable," by H. E. Ives of the Bell Telephone Laboratories; and "The In-

fluence of *p*H on Washing Films after Processing," by S. E. Sheppard and R. C. Houck of the Eastman Kodak Company, Rochester. The former paper was presented by L. F. Brown of Electrical Research Products, Inc., and the latter by R. B. Atkinson. A résumé of the proceedings of the Washington Convention was presented by J. G. Frayne.

ERRATUM

RESEARCH COUNCIL STANDARD NOMENCLATURE FOR RELEASE PRINT SOUND-TRACKS

In the June, 1938 issue of the JOURNAL, beginning on page 656, appeared the above-entitled article by John K. Hilliard, describing the Academy Standard sound-track nomenclature approved by the Research Council of the Academy of Motion Picture Arts and Sciences and published in the Academy Research Council Technical Bulletin of November 24, 1937.

As reprinted in the JOURNAL, the article employed the term "variable-width" throughout, instead of the term "variable-area" as approved by the Research Council in the original publication.

The entire Standard Nomenclature is now under consideration by the Sectional Committee on Motion Pictures of the American Standards Association, and if adopted these terms will hereafter be used throughout the industry to designate the various indicated types of sound-track.

In particular, the term "variable-area" has been approved by the studios and by the equipment companies involved to designate that type track, throughout the industry.

Readers of the JOURNAL should, therefore, in the above-mentioned article substitute the term "variable-area" whenever designating that type of track, instead of the term "variable-width."

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXXI **SEPTEMBER, 1938** **Number 3**

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JOURNAL
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A WATER-COOLED QUARTZ MERCURY ARC*

E. B. NOEL AND R. E. FARNHAM**

Summary.—*The structure of the water-cooled quartz mercury lamp, its operation, quality of radiation, brightness, and source size limitations are first described, followed by a discussion of the power-supply equipment, both a-c. and d-c. Applications of the lamp are as follows:*

(*1*) *Motion picture projection, with single lamps and with several sources.*

(*2*) *Motion picture photography, both black-and-white and color, and the application to very high-speed motion picture photography. For black-and-white photography the lamp is quite satisfactory. For color work the relatively limited red radiation may call for external methods, either in the use of fluorescent reflectors or a highly red-sensitive emulsion, to make up for this deficiency.*

(*3*) *Film printing. Because of the relatively high output in the blue-violet and ultraviolet regions this lamp may prove a very satisfactory source, especially where advantage is taken of the ultraviolet radiation.*

The following additional applications, of secondary interest to the motion picture industry, are also discussed: photo-enlarging, photoëngraving, and searchlights.

Within the past few years a number of new mercury-vapor light-sources have made their appearance.[1] New materals and technics have made possible operation at temperatures and pressures far above previous values and at which the characteristics of the light emitted differ greatly from those of the older type of mercury source It is the purpose of this paper to discuss the work done at Nela Park on one of the newest developments—a water-cooled quartz mercury lamp operating at a pressure of about 1100 pounds per square-inch—and some of its possible applications in the motion picture industry

Construction of the Lamp.—A 1000-watt lamp of this type is shown in Fig. 1(*A*). It consists of a quartz tube about 40 mm. long having an outside diameter of 6 mm. and a bore of 2 mm. Sealed into each end by means of a special glass are tungsten wires which are both the leads and the electrodes. The tips of the wires project just through the surface of a small quantity of mercury located in each end of the

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 20, 1938.

** General Electric Co., Cleveland, Ohio.

lamp. In order to aid in starting, the lamp is filled with argon gas at 50 mm. pressure. Other characteristics are listed in Table I.

When not lighted, the internal pressure is that of the argon gas, namely, $^1/_{15}$ of an atmosphere. However, when lighted, the heat from the arc vaporizes some of the mercury in the pools around the electrodes, building up a pressure of the order of 75 atmospheres, the exact value being determined by the wattage input and the distance by which the electrodes project from the surfaces of the mercury.

TABLE I

Characteristics of 1000-Watt Water-Cooled Quartz Mercury Lamp

Arc Length	25 mm.
Inside Diameter	2 mm.
Outside Diameter	6 mm.
Operating Pressure	75 atm.
Watts	1000
Operating Volts	840
Operating Amperes (a-c.)	1.4
Lumens per Watt	65
Lumens	65,000
Max. Surface Brightness (initial)	30,000 candles/cm^2.
Burning Position	Horizontal

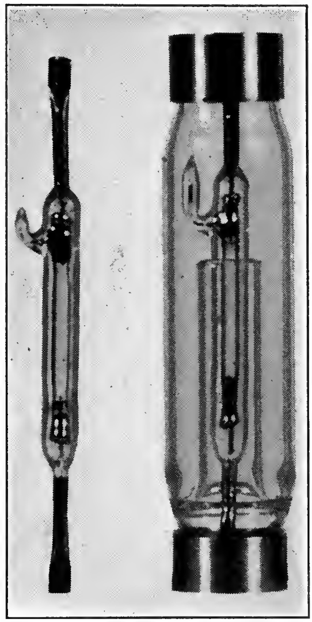
In order to be able to dissipate 1000 watts within such a small volume the lamp must be cooled very effectively. It is not sufficient merely to place the lamp in a bath of water; the water must be passed over the lamp with enough velocity to prevent the formation of steam bubbles on the surface of the quartz. Placed around the lamp is a "velocity tube" having a radial clearance from the lamp of about 1 mm., through which the water must flow. Because of this restricted cross-section, more than ample water velocity is attained to prevent the formation of steam with a water flow of about three liters per minute. In passing over the lamp the increase in water temperature is only a few degrees Centigrade.

One type of cooling jacket is shown in Fig. 1(*B*). Water enters at one end and leaves at the other, while electrical connections are made at each end of the jacket on the brass rings. A socket for this type of jacket is shown in Fig. 2, while Fig. 3 shows one designed to take two such lamps.

Since both leads to the lamp are in contact with the water, the arc operates in parallel with a water resistance. Where the water surrounding the lamp has a large cross-section the resistance is low

enough to interfere with the operation of the lamp. With a "velocity tube" around the lamp, however, the cross-section of the water is small enough so that the current through the water is only 10 to 25 milliamperes.

Spectral Distribution of the Discharge.—Incandescent sources, such as tungsten and the crater of a carbon arc, emit a continuous spectrum; that is, all colors of light are given out. Luminous vapors and gases, however, emit only certain colors which are characteristic of the substance. Fig. 4 shows the spectra of a number of commercial mercury-vapor sources and the spectra of a water-cooled quartz mercury lamp operating at various pressures. The spectrum of the Cooper-Hewitt lamp operating at 0.0003 atmosphere shows only a few distinct lines. That of the *H-1* operating at 1.4 atmospheres appears to be little different. The *H-4* lamp spectrum at 8 atmospheres shows the presence of a very weak "background radiation"—the colors between the mercury lines are beginning to fill in. At 25 atmospheres (the *H-3* lamp), the background is somewhat stronger; and, in addition, it will be noticed that the main spectral lines are no longer sharp, the blurring being more pronounced on the long-wave side.



(*A*) (*B*)

FIG. 1. 1000-watt water-cooled quartz mercury lamp: (*A*) the lamp proper; (*B*) the lamp in place in its water jacket.

With the water-cooled lamp the current densities and pressures are so much greater that the lines are even more blurred and the continuous background forms a very appreciable portion of the radiation.* The spectral distribution curves of Figs. 5 and 6 may show this even better. At the highest loading, shown in Fig. 6(*D*), the lamp life is quite short, but if a better material than quartz becomes available lamps operating at this pressure may be practicable.** The emitted

* Pressures are calculated from the formula[2] $P_{atm} = (\text{Gradient} - 100)/3$.

** *Cf.* footnote p. 9.

light contains appreciable red, as shown by Table II.[4] The effect of this upon the rendition of skin tones is quite noticeable.

As the pressure is increased still further, the lines merge more and more into the background until they disappear completely. Mr. Cornelias Bol, who did the original work on these lamps at The Philips Co. in Holland, and who is now associated with our Company, has

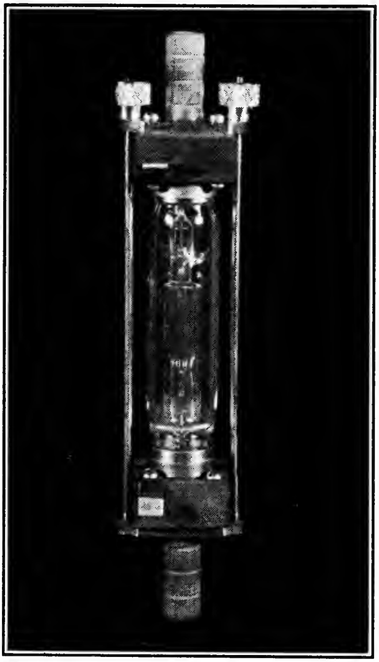


FIG. 2. Single-unit socket with lamp and jacket in position.

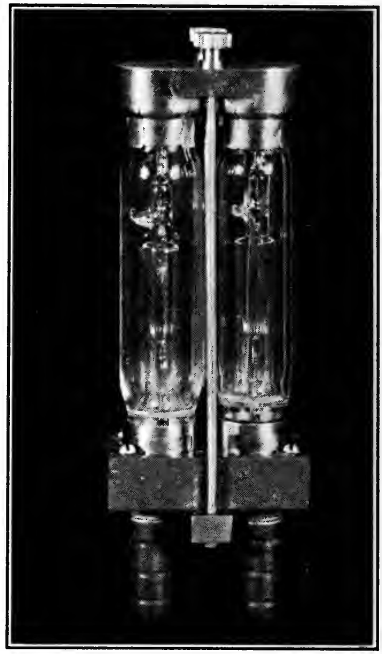


FIG. 3. Socket for two lamps. The cap is hollow, to allow the water to flow up through one lamp and down through the other.

been experimenting with mercury discharges at extremely high pressures at Stanford University. By enclosing a lamp in a bomb-like vessel and subjecting it to an external pressure of 10,000 pounds per square-inch to prevent it from bursting he obtained the spectrogram of Fig. 7, which at the highest voltage per centimeter and pressure shows complete absence of lines. It shows also that as the pressure is increased, there is less and less short-wave ultraviolet emitted.

	Volts	Amps.	Watts	Atmo. (*circa*)
Quartz Capillary No. 128 on D-c.	2100	1.5	3150	250
	1900	1.06	2070	230
	1740	1.14	1980	200
	1500	1.17	1750	170
	1200	1.22	1460	130
	840	1.26	1060	80
	600	1.33	800	50
H-3			85	25
H-4			100	8
H-1			400	1.4
Cooper Hewitt (D-c.)				0.0003

FIG. 4. Spectral characteristics of various mercury lamps.

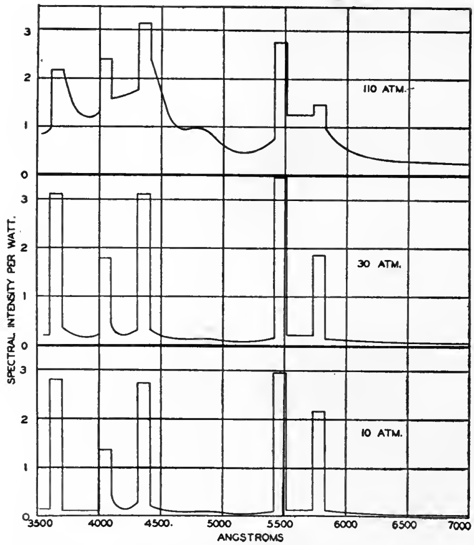


FIG. 5. Spectral energy distribution curves for water-cooled lamp (*top*) and two air-cooled lamps (*below*). The ordinates are milliwatts per 100 Ångstrom units per steradian per watt input.

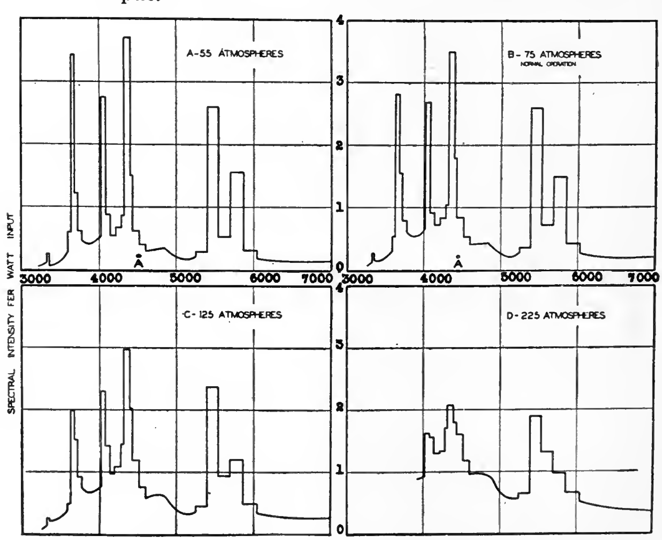


FIG. 6. Spectral energy distribution curves for a water-cooled quartz mercury lamp operating at different pressures. The ordinates are milliwatts per 100 Ångstrom units per steradian per watt input.

The alteration in the spectral distribution as the pressure is increased is such that the color of the light is materially changed. In air-cooled lamps at very low pressures the discharge is distinctly greenish, but as the pressure is raised, the color becomes more and more white. These changes are plotted in Fig. 8 on the standard I.C.I. color-chart. On this chart the points for pure spectral colors lie on the large boundary curve as marked, while those for unsaturated colors lie inside. The dominant hue is determined by the direc-

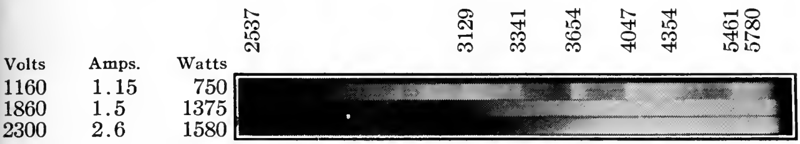


FIG. 7. Spectrogram by C. Bol at Stanford University: quartz mercury arc with gap of 10 mm. and bore of 1 mm. operating in steel container with the circulating water under a pressure of 10,000 lbs. per square-inch.

tion, and the saturation by the distance from the daylight point. It may be seen, as the pressure of mercury is increased in the series of lamps tested, that while the hue changes from green to yellow-green

TABLE II[3]

Percentage of Total Light from Mercury Arcs Operating at Various Pressures, from Sun, from a Tungsten Lamp, of Wavelength 6000–7600Å

Source	Mercury Pressure in Atm.	Per Cent of Light 6000–7600Å
Cooper-Hewitt	0.0003	0
H-1 Lamp	1.4	1.0
H-4 Lamp	8	1.7
H-3 Lamp	29	1.9
Water-Cooled Capillary Arc	110	7.0
Sun		20.0
500-Watt, 115-Volt Tungsten		27.0

to blue, the light actually becomes very nearly white as shown by the closeness with which the points for high-pressure operation approach the daylight point.

Brightness of the Discharge.—Even more unique than the fact that these lamps have appreciable continuous radiation is their intrinsic brightness. Fig. 9 shows the brightness of water-cooled lamps oper-

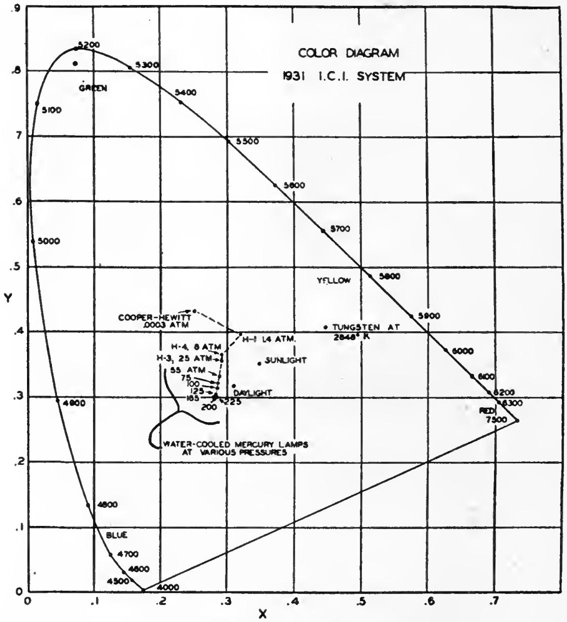


FIG. 8. Color coördinates of mercury lamps operating at various pressures.

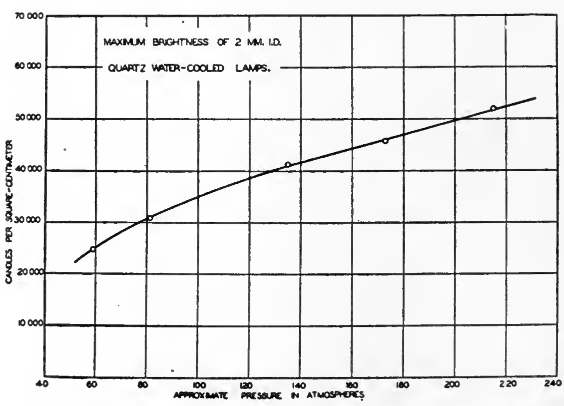


FIG. 9. Maximum brightness of water-cooled mercury arcs operating at various pressures in tubes of 2-mm. inside diameter.

ated at various pressures.* These figures should be compared with the brightness of a 1000-watt projection lamp, which is 3100 candles per square-centimeter and that of a crater of a carbon arc, which ranges from 14,000 candles per square-centimeter for the regular type to 50,000 to 86,000 candles per square-centimeter for the high-intensity type. The brightness of the quartz lamp is essentially constant along the length of the arc, but across the arc stream it varies as shown in Fig. 10. Since it is a line source of light, for some applications, several must be used side by side, or the more usual type of optical systems must be modified for use with a source of this shape.

TABLE III

Comparison of Energy Radiated in the Ultraviolet, Visible, and Infrared Portions of the Spectrum by a 1000-Watt Quartz Water-Cooled Mercury Lamp and a 1000-Watt High-Efficiency Biplane-Filament Lamp. (For the Tungsten Lamp the Figures Are for Energy Radiated beyond the Bulb by the Filament)

		1000-Watt Biplane at 27.5 LPW	1000-Watt Water-Cooled Mercury
Ultraviolet	(3000–4000 Å)	5 watts	20 watts
Visible	(4000–7600 Å)	145 watts	284 watts
Infrared	(7600–14,000 Å)	690 watts	76 watts
Total watts radiated		840	380
Lumens		27,500 lumens	65,000 lumens

Coolness of the Light.—One of the most valuable characteristics of the lamp is the coolness of its light. This is illustrated in Table III, where a 1000-watt quartz lamp is compared with a high-efficiency biplane lamp. It will be seen that for equal lamp wattage the quartz lamp radiates more than $2^1/_3$ times the light but only 45 per cent of the energy of the tungsten lamp. Thus, to supply an equal amount of light, only 42 per cent as much wattage is required in a water-cooled quartz lamp as with the tungsten-filament source, and the radiated energy is reduced to one-fifth. If the comparison were to be made on the basis of photographic effectiveness, the result would be even more favorable to the mercury lamp.

* De Groot's formula[2] is based upon data taken up to 150 atmospheres and 550 volts per centimeter. It has been used here with values of gradient up to 750 volts per centimeter, so that pressures above 150 atmospheres should be considered as only approximately accurate.

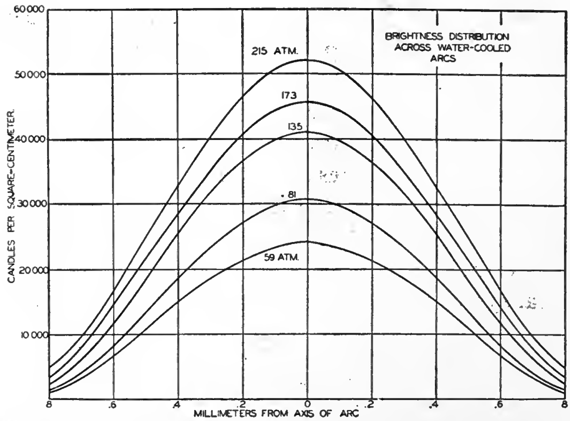


FIG. 10. Variation in brightness across water-cooled mercury arcs operating at various pressures in tubes of 2-mm. inside diameter.

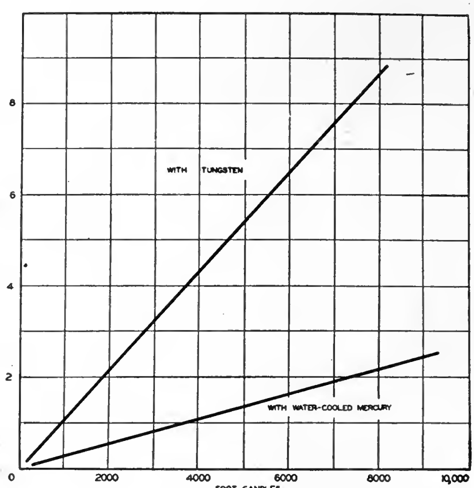


FIG. 11. Increase of temperature (Centigrade) of a portion of the skin (lower arm) upon irradiation with light from tungsten lamps and water-cooled mercury arcs. For equal increases in temperature $4^1/_2$ times as much mercury light can be employed as incandescent lamp light. (E. G. Dorgelo, *Philips Technical Review*, June, 1937.)

Another way of illustrating the coolness of this light is by means of Fig. 11, which gives the relative increase of temperature of the skin with tungsten and with water-cooled mercury illumination.[4] For equal increases in temperature $4^1/_2$ times more mercury illumination can be used than tungsten. This is important for many applications.

Operation of the Lamp.—On 60-cycle a-c. operation there is a pronounced 120-cycle flicker, which is clearly evident in Fig. 12. By operating three lamps on three-phase the flicker can be sensibly eliminated as shown by the oscillogram of Fig. 13.

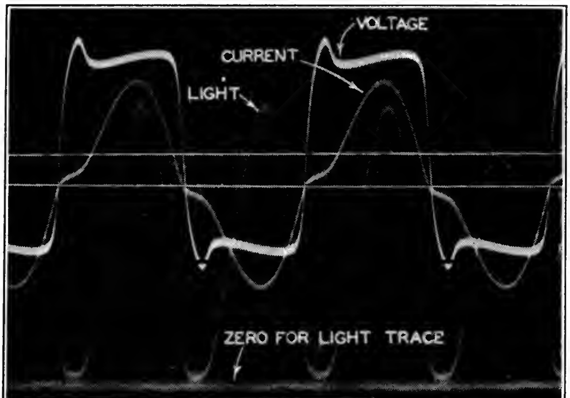


FIG. 12. Current, voltage, and light traces for 1000-watt water-cooled mercury arc operating on a 60-cycle supply.

The lamps reach full brightness within a second or two after the switch is closed. Since their heat storage is small and cooling rapid, unlike the air-cooled high-intensity lamps they may be restarted at once after the current has been turned off.

During life the lamp voltage gradually increases and the current and wattage decrease. The useful life is terminated by failure to start or by fracture of the quartz bulb. Although the operating pressure is high, the volume is so small that failures are not violent. However, because the lamp is surrounded by water the outer jacket is subjected to a shock when a lamp fails and may crack, presenting a possible hazard of high voltage and running water. Where necessary a switch actuated by water line pressure can be installed to turn off the power should a jacket break.

The life of the lamp is dependent upon the number of times it is started and the type of service in which it is used. Although still in the developmental stage it is felt the life is satisfactory for many special applications.

Equipment.—For a-c. operation of the 1000-watt lamp the high-reactance transformer shown in Fig. 14 is used. The secondary supplies 1200 volts on open circuit for striking the arc. At the instant of starting, the arc voltage is so low that it is practically a short circuit on the winding, and the impedance of the unit limits the current

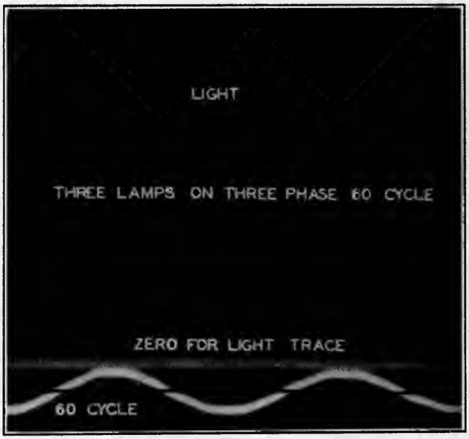


FIG. 13. Oscillograph of ripple in combined light output of three lamps operating on a three-phase 60-cycle supply.

in this case to 2.6 amperes. As soon as the inside tube walls become warm the pressure builds up and the voltage increases to 840 volts, while current automatically drops to 1.4 amperes.

The lamps operate on ballasted direct current with about 15 per cent less current than on alternating current. D-c. operation is in many ways more satisfactory, but the generator or rectifier equipment is much more bulky than the transformer.

The lamp may be run for 15 to 30 seconds in dish or bulb filled with glycerine, but for any longer periods of operation it must be run in flowing water. The lamp surface must be cleaned occasionally with dilute HCl to remove deposits, the frequency depending upon the salts in the water supply. Recirculating cooling systems have been

built employing a pump and radiator, but even then it is necessary occasionally to clean the lamp.

Several kinds of sockets have been designed for this lamp, depending upon the use intended. Fig. 15 shows a different type of single unit in which the replaceable part is merely the lamp itself with brass ends. Figs. 16 and 17 show two styles of jackets employing three of this same kind of lamp.

Since the lamp is still in the developmental state, actual experience with its possible applications is limited Any analysis of the possible future application of the water-cooled unit must, accordingly, be

FIG. 14. Transformer for operating 1000-watt water-cooled mercury lamp on 110- or 220-volt, 60-cycle lines.

based upon a consideration of the characteristics of the lamp with respect to the requirements of the several potential services.

The forms of lamp illustrated above provide maximum performance, ease of replacement of the elements, and compactness. Some modification of present forms may be necessary for adaptation to a particular service; but the capillary tube is an essential feature and fixes the width of the lighting element. In summary, the chief characteristics are these:

(*1*) *Source dimensions.*—1 mm. by 25 mm. for 1000 watts. Complete assembly compact.

(*2*) *Light output.*—65 lumens per watt; steady on d-c.; cyclic variation almost reaching zero on single-phase a-c. but causing only slight ripple on three-phase a-c.

(*3*) *Power supply*.—High voltage (840 volts a-c., or d-c. for 1000 watts); current—1.4 amperes a-c., 1.2 amperes d-c.

(*4*) *Source brightness*.—30,000 candles per square-centimeter.

(*5*) *Light distribution*.—Characteristic of a linear source of light.

(*6*) *Spectrum*.—Continuous, but with most of the light emanating from peaks

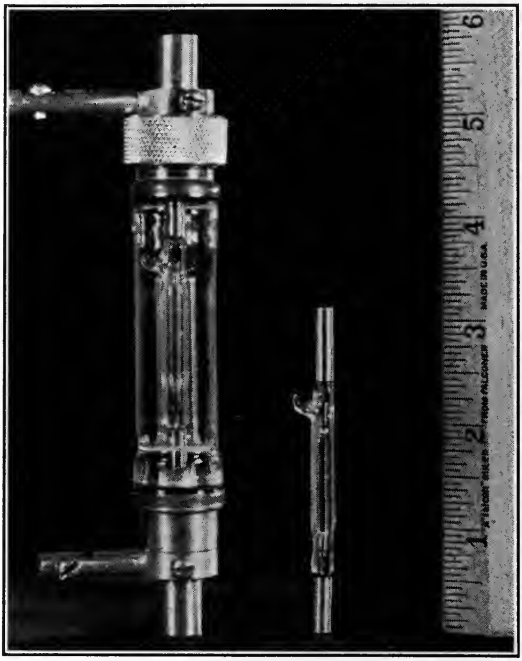


FIG. 15. Socket and jacket combined, in which the replaceable element is the lamp itself, shown on the right.

at 5600 Å (yellow-green), 4350 Å (blue-violet), 4100 Å (violet), and 3650 Å (near ultraviolet).

(*7*) *Cooling system*.—Circulating water, self-contained system or from mains. More than 90 per cent of infrared (heat) radiation absorbed by circulating water.

The following discussion will serve briefly to indicate the effect of such characteristics upon several phases of lighting for photography and projection.

MOTION PICTURE PRODUCTION

Black-and-White, and in Color.—The high brightness and concentration of source provide the requisite beam control and efficiency of light utilization with both lens and reflector equipments. To pro-

vide an adequate amount of light several capillary elements may be grouped together in a single reflector or equipment. The color of the light is satisfactory for black-and-white photography, although the "red" of the properties may have to be intensified for correct rendition. A definite advantage in respect to the comfort of the actors

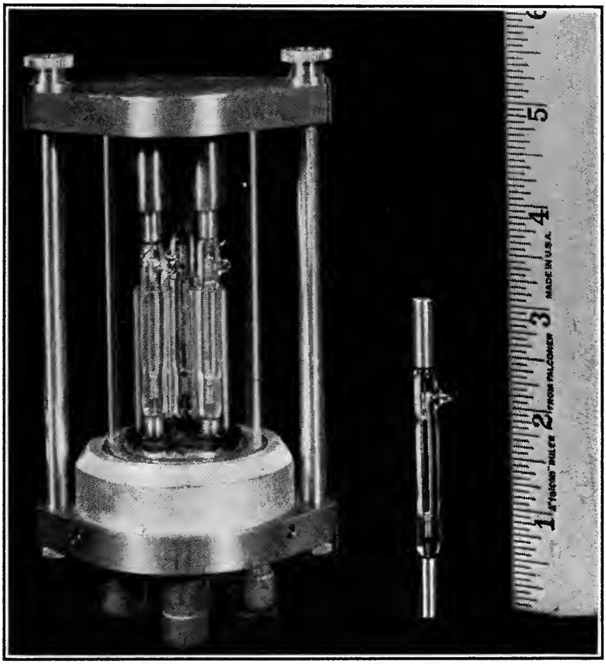


FIG. 16. Socket for three lamps for single- or three-phase operation, with the lamps in a triangular arrangement.

results from the very small proportion of infrared radiation. The spectral quality of the light is not adapted to present color processes, nor can it be rendered suitable by filtering alone.

The camera shutter or the movement of the film must be synchronized if the lamps are operated on a single-phase a-c. supply. Direct current or the combination of several elements on three-phase alternating current eliminates this requirement. The cooling system should be self-contained, since portability of equipment is important in studio practice.

Ultra Speed.—The extremely high light-intensities necessary for photography at 1000 or more pictures per second can easily be obtained because the compact equipment can be placed close to the area being photographed. But the greatest advantage is that there is no heat problem. For example, it has been possible to take 1000 pic-

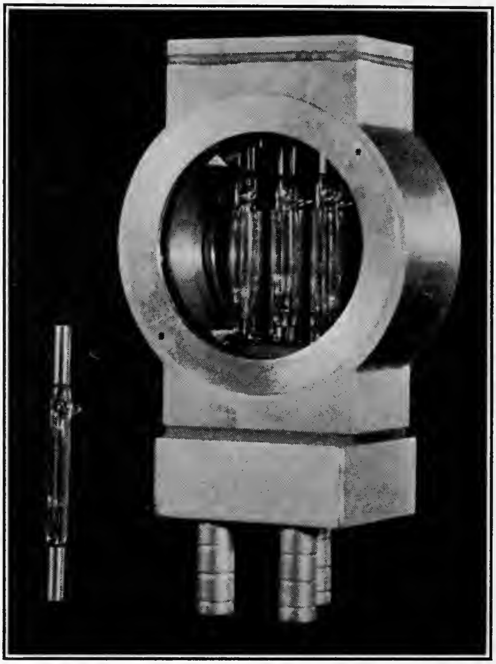


Fig. 17. Socket for three lamps, for single- or three-phase operation, with lamps arranged in a plane.

tures per second, *i. e.*, $^1/_{4000}$th second exposure on positive film at $f/2.0$ with no discomfort.

Three-phase alternating or direct current are necessary unless single-phase alternating current of the picture frequency or a multiple thereof is obtainable.

Trick and Background Photography, Animation, Tilting.—For processes involving the illumination of a copy-board this linear source in a trough reflector of parabolic and cylindrical cross-section produces high uniform illumination with minimum heat. Where a pic-

ture is projected to a screen and rephotographed, the water-cooled lamp can be used as the projector light-source. Color photography is practicable to a limited extent by intensifying the reds.

Film Printing.—The relatively large proportion of ultraviolet radiation suggests the use of the water-cooled lamp for motion picture printing and production of duplicate negatives. The high source brightness lends itself well to optical printers. Direct current is necessary where the film moves continuously.

Sound Recording.—Adaptability to optical control and the favorable color of the light make it especially applicable to sound recording with both the light-valve and galvanometer systems. Direct current is necessary to eliminate parasitics.

TELEVISION STUDIOS

The color of the light from the liquid-cooled capillary lamp matches well the characteristics of the iconoscope, which is sensitive particularly to the blue-green. The suppression of the infrared is important in avoiding chromatic aberration. Since illumination levels must be very high, the cooler light is a boon to the artists.

MOTION PICTURE PROJECTION

The length of the source is not too great to be efficiently utilized in a motion picture projector. The width is insufficient to fill the lens system unless a cylindrical surface is incorporated. Several sources and images may be aligned side by side to provide adequate illumination for large screens. The color of the light seems satisfactory for black-and-white pictures. For color pictures, reds must be exaggerated in the film. If the pictures are also taken under capillary lamps, the intensification of the reds would therefore have to be compounded.

PHOTOËNGRAVING

Two steps are involved in photoëngraving: taking of the negative and printing on metal. For the former the copy-board must be illuminated from the sides, a condition to which the line source of the water-cooled lamp lends itself admirably. Color copy is photographed through red, green, and blue filters. Therefore, any discrepancy in the light output in the respective colors can be compensated for by the exposure ratios. The unmodified color of the mercury arc corresponds very closely with the requirements of the printing processes.

BLUE-PRINTING

The same advantages that make the lamp applicable for printing on metal in photoëngraving make it worth while for blue-printing, *i. e.*, large amount of light of a color favorable to the sensitivity characteristics of the photochemical materials.

PHOTO MURAL ENLARGING

There is no entirely satisfactory source now commercially available for enlargers used in making photo murals. The need for compactness, spectral quality favorable to the bromide emulsion, as well as freedom from heat, are amply met in the new source.

Source shape, high brightness, and color will be found favoring conditions in other projection sources, such as searchlights and airport lighting. In general, the water-cooling system can be either self-contained, with circulating pump or thermo-syphon, or connected to the city mains. Where portability of equipment is important self-contained cooling will obviously be indicated.

In order to minimize high-voltage wiring, transformers may be incorporated in the equipment. For d-c. operation, a rectifier-filter system or a d-c. generator appear equally feasible. The transformer supplying the high voltage to the rectifier and filter can have high leakage reactance, thus practically eliminating ballast losses. The advantage lies with the generator when a number of lamps are to be employed.

In conclusion, it may be said that the ultra-high pressure quartz mercury lamp may find suitable application in several places in the motion picture field. Water-cooling and high voltage are necessary, and in some cases it may be desirable to employ a pressure-actuated switch to eliminate the hazard of running water and high voltage in the case of a jacket failure. The advantages are compactness, high efficiency, high actinic value, and remarkably high ratio of lumen output to radiated energy.

The authors wish to express their thanks to D. D. Hinman, A. L. Shrider, M. A. Easley, and Dr. B. T. Barnes of the Lamp Development Laboratory at Nela Park for many of the measurements made on these lamps.

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DISCUSSION

MR. KELLOGG: Relative to the visible light, the ultraviolet of a high-pressure arc is very much less; but does it decrease as the wattage and pressure increase, or do they increase together, the visible portion increasing very much faster? Also, is the life with d-c. as long as with a-c? That is, for the same number of startings?

MR. NOEL: The life is good with either a-c. or d-c. The long-wave ultraviolet increases as the pressure is raised, but the short-wave ultraviolet in the neighborhood of 2537Å is absorbed.

MR. RICHARDSON: I understand it is proposed to use several of these lamps together, as a projector light-source. The light would have to pass through the water jacket and several thicknesses of glass. Would you be able to obtain the effect of a solid light-source?

MR. NOEL: I believe so. The water absorbs infrared but not very much visible light; and since the water and glass are in contact there is little loss at that point.

MR. KELLOGG: With regard to the light distribution, in spite of a large increase in the red as well as in the blue there is always a range of very little radiation, I should say, in the green. That is not due to absorption, is it?

MR. NOEL: No, it is not.

MR. DURAT: In using a bank of the lights, would it not be preferable to place them all in a single bath of water so as to have less refractive effect?

MR. FARNHAM: I do not think we should try to control the light within the water unit. The water merely provides a means of getting the heat away from the lamp.

MR. DURAT: I was thinking of an auxiliary water jacket, not to cool the lamps but to act as a medium through which the light could pass.

MR. NOEL: I see no objection to that, although we have no trouble with the lamps we have shown.

NEGATIVE-POSITIVE TECHNIC WITH THE DUFAYCOLOR PROCESS*

T. T. BAKER**

Summary.—*Progress in two directions has greatly simplified making prints from screen-film negatives. The study of emulsion characteristics and of the mechanics of development with silver bromide solvents has led to the avoidance of color dilution in copying one screen material from another. Sodium thiosulfate in a metol developer has been shown to localize development in the lower strata of the film, so that the silver image is formed in close contact with the reseau, largely eliminating scatter at the boundaries of differently colored units; the crystalline structure of the silver salts and grain-size frequency also assist in preventing scatter. Residual color dilution as the result of the 45-degree oriented reseaux is explained, and the way in which this has been counteracted by suitable choice of gammas in the negative and positive material. The production of a vapor-lamp emitting the line spectra of mercury and cadmium without appreciable spectral background, combined with a liquid didymium chloride filter has provided a triple monochromatic light-source, the spectral lines of which coincide with the peaks of the reseau transmissions, thereby eliminating dilution of color due to overlap, such as has always previously been present with color filters of the narrow-cut type. The Dufaycolor contact printing machine with automatic control of both hue and printing light is described. The technics of printing, and development with standard equipment, are described.*

A good deal has been said from time to time about the copying of one color-screen material upon another, the fidelity of the copies, and so on, and during the past two years a great deal more has been said about making screen positives from screen negatives. In this paper will be described the details of the negative-positive process, which has furnished a solution to making commercial screen-mosaic cine prints by the Dufay process.

In talking about additive processes, it should be remembered that *all* color photographs are today taken by an additive analysis; that is, by recording the blue-violet, green and red components. But whereas in subtractive cases the separations are used as a basis for making continuous tone prints, in screen processes the negative

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received May 9, 1938.

** Dufaycolor, Inc., New York, N. Y.

separations are usually reversed to positive, the one color matrix providing the additive filters for viewing by the retinal process of confusion.

In Dufaycolor negative-positive technic the same matrix is used as base for both negative and positive emulsions. A photomicrograph of it is seen upon the screen; the individual blue and green rectangles are approximately 19 to the millimeter. Taking one blue and one green rectangle, and the piece of red line contiguous as a complete "unit," the areas of the three elements are balanced so as to give white on projection. The average of a number of readings made on a special form of trichromatic colorimeter provides a numerical assay of the balance of the unit, and variations from neutrality are kept within limits of tolerance that have been agreed upon as the result of considerable visual test. This point is mentioned because, even with the precision control of the relative areas in the unit, minute deviations invisible to the eye can suffice to cause off-balance in printing. The degree of off-balance in any particular reseau is measured, and a code number is obtained designating the minus-filter combination required to give the hue correction.

FIG. 1. Cadmium-mercury-vapor lamp. (*Courtesy British Thompson-Houston Co., Ltd., Rugby, England.*)

The negative must thus be graded for color as well as density, and as printing is effected by light consisting of three monochromatic bands, the color correction is obtained by means of three sets of compensating filters each designed to reduce the intensity of one of the bands without affecting the others. Minus colors of the cyan, magenta, and yellow type, but actually complementaries of the reseau colors, are used, and these filters are dropped into the light-beam by means of light electromagnets operated by relays the excitation of which is controlled by metal staples in the perforations of a separate master film. The film is provided with two series of these metal staples, and passes through two distinct contact boxes; one contact box actuates the magnets introducing the necessary combinations of neutral gray filters to effect control of light intensity. The Lawley printer has lent itself well to these two methods of control, the stapling being done on a full-length black-and-white print

from the negative so that the latter can not be mechanically damaged. A separate feed and take-up are provided for the control film.

The light-source is of prime importance in making screen prints. Originally a Mazda lamp was employed, and narrow-cut gelatin filters, that removed from the white light those portions of the spectrum that were common to any two of the reseau primaries. These overlap quite considerably, and the overlap is greatly magnified in printing, causing marked dilution of color. Such filters are very inefficient, and G. B. Harrison in England some time ago devised a light-source composed of a mixture of mercury vapor and red filtered Mazda.

Recently, however, cadmium has been introduced into high-pressure mercury-vapor lamps, and such a mercury-cadmium lamp, running at a pressure of about 1 atmosphere, has provided an elegant solution of the problem of producing a "tri-monochromatic" light-

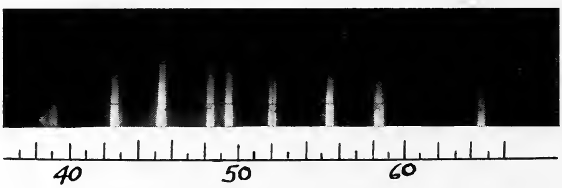

FIG. 2. Mercury-cadmium lines.

source. The cadmium-mercury-vapor lamp shown in Fig. 1 is at present made in England but a great deal of experimental work has been done on it in this country; much valuable information was published on the subject recently by Marden, Beese and Meister,[1] who give the figures in Table I for the distribution of light from cadmium, as measured with a monochromator, thermopile, and galvanometer:

TABLE I

Cadmium (% in Visible)

Line	Low Pressure	High Pressure*
6438 Å	9.2	17.8
5086	61.0	58.0
4800	23.7	14.1
4678	6.1	5.4

* Corrected for eye sensitivity.[2]

The overall efficiency of the lamp is somewhat lower than that of the plain mercury type, the visible radiation being about 75 per cent only of the 10 or 12 lumens per watt mentioned by Dushman at the Fall Convention.[3]

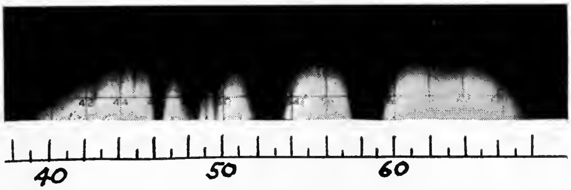

FIG. 3. Absorption of saturated solution of didymium chloride.

The mercury-cadmium lines are shown in Fig. 2, and it will be seen that there is a very strong element of red, actually about 6 per cent, added to the familiar mercury line spectrum. Three lines are used for printing, one in the blue-violet, one in the green, and one in the red, at 643 mμ, 546 mμ, and 436 mμ. The remaining lines are ex-

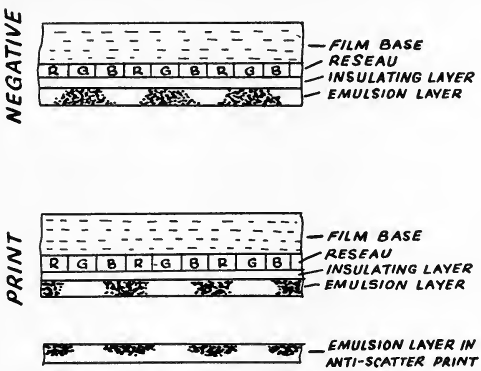

FIG. 4. Showing relation of reseau to emulsion layer.

tinguished by means of a composite filter, the chief component of which is a 3-inch deep liquid cell containing a saturated solution of pure didymium chloride. The marked absorption of this salt is seen in Fig. 3. As luck will have it, the absorption bands come in the most fortunate places, totally eliminating, for example, the yellow

mercury lines, which would otherwise pass through both red and green reseau elements, causing green to add to red and so give orange, or red to add to green and so give orange-greens. The lamp can, of course, equally be used in an optical printer.

When in 1928 the first serious attempts at negative-positive films were made in Paris, by Louis Dufay, Charles Bonamico, and the author we experienced considerable color dilution in making prints from the screen negatives. Several thousand feet of negative were made in the South of France, on 8-line per millimeter reseau, and prints from these on 15-line reseau were shown at the Pavilion Theater, London, nearly ten years ago! These pictures were scenes of an act by artists in an orange grove, and it is curious that the

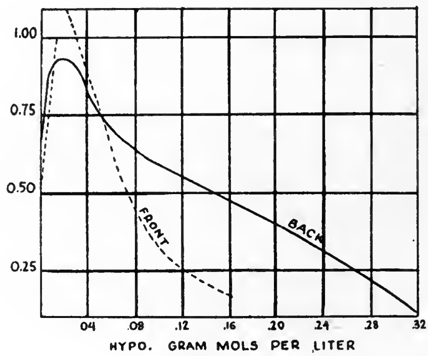

FIG. 5. Development in upper and lower layers of emulsion film. (*Reproduced from Phot. J.*)

oranges themselves and the blue-greens of the foliage were quite saturated, while all other colors were badly diluted. It soon became evident that two factors were at work in causing color dilution. Irradiation at the reseau element boundaries was one. The light scatter increased as the thickness of the insulating varnish layer between emulsion and reseau increased; for this reason the thickness of the insulating coating was reduced to between 3 and 4 microns. The importance of this thickness from the point of view of scatter must be emphasized. The other cause was the decided overlap of the additive reseau colors. The reason for the purity of the orange and blue-green colors in these early prints was probably minimized scatter in these regions owing to very decided minima in the spectral

sensitivity of our emulsion at that time. D. A. Spencer[4] in 1933 drew attention to the results of light scatter within the emulsion—actually the irradiation referred to—and pointed out[5] that the desaturating effect is common to negative-positive and successive reversal processes. He also points out that the effect of a silver bromide solvent (ammonia, thiocyanate, thiosulfate, *etc.*), which is ordinarily used in first development in reversal processing, causing the degree of development occurring under adjacent color elements to become exaggerated, is offset by the opposite effect of scatter in subsequent reversal, but that it is not so offset when developing as a

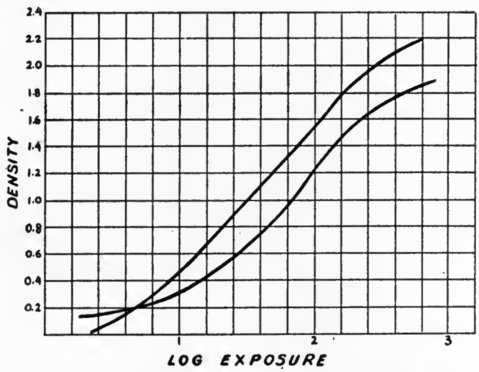

FIG. 6. Characteristic curve: *upper curve:* developed as negative in *DK50; lower curve:* reversed. (Note: The (lower) reversal curve has been plotted in reverse position for better comparison.)

negative. Spencer has found that by the use of hypo as a silver bromide solvent in the developer, the developed image is confined to the lower layers of emulsion grains—that is, of course, those nearest the reseau, and is what we want (Fig. 4). The solubility of silver bromide is much greater in sodium thiosulfate solution than potassium thiocyanate or ammonia. One hundred grams of solution containing 10 grams of $Na_2S_2O_3$ at 20°C will dissolve 3.50 grams of AgBr; a similar solution of potassium thiocyanate at 25°C will only dissolve 0.73 gram of AgBr; 34 grams of NH_3 at 0°C in 100 grams water dissolve 1.987 grams of silver bomide.[6] A metol-caustic soda bath containing hypo (of the type given in a previous paper[7]) is being used. Sodium thiosulfate added to a metol developer produces an increase in density, the increase rising to a maximum with increasing concen-

tration and thereafter falling off progressively,[8] but when the developing solution contains a concentration greater than that that shows the maximum effect, it produces relatively more active development in the depths of the emulsion than in the surface layers (Fig. 5).

Scatter has to be prevented as far as possible by using emulsions of as fine grain as is consistent with the necessary speed; here the knowledge of the emulsion maker in preselecting symmetrically shaped AgBr crystals, adequately peptized, and an emulsion with a long grain-size frequency curve, has proved of considerable value.

Increase in latitude is one of the most important features of the negative-positive process. Recent comparisons made of reversals against negatives developed in suitable baths show comparative latitudes (as measured on the characteristic curves between a γ of 0.25 at foot and shoulder), of 0.95 reversal against an average of 2.2 negative (Fig. 6). It is thus possible to deal in negative technic with a greatly improved range of lighting intensity. Control in development, however, is somewhat difficult, as with most emulsions applied in the low coating weight necessary for color-screen work,* gamma infinity is reached very rapidly (Fig. 7). We work, therefore, with very dilute baths. Dilution of color is inevitably caused in these prints where the negative and positive reseau elements cross, by microscopic white spaces occurring at the overlapping corners; for this we endeavor to compensate by stepping up the gamma of the print to make the screen contrast as high as permissible, this having the physiological effect of increased saturation. The negative material has the red lines running at an angle of 27 degrees to the edge of the stock, with the lines of alternate blue-green elements running at right angles. In print stock the lines are inclined at an angle of 45 degrees. This orientation is chosen so that there is no danger of moire when one reseau is printed on the other. But in printing it necessarily happens that there are portions

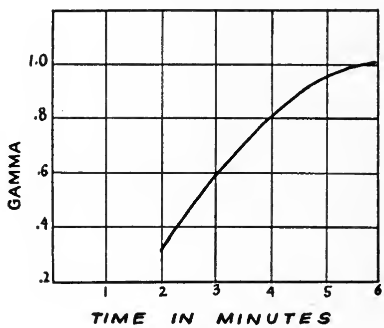

FIG. 7. Gamma-time curve.

* About 60 mg. of silver halide per sq. decimeter.

of many reseau elements that are overlapped by portions of elements of another color, and in these local spots of double filtration not enough light is transmitted to produce a developable effect upon the emulsion; hence the spots appear white in the silver image, thereby causing the effect of color dilution.

In split-beam camera work it is recognized that the separation must be substantially correct, and the balance of the three images correct, if satisfactory subtractive prints are to be obtained. It is equally important that in a screen negative the three intermingled images—for after all there *are* three images—be correctly balanced and in equally sharp focus. The latter is, of course, taken care of by choice of a reasonably apochromatic lens. But the color-balance needs to be quite accurate, compensation being possible in printing for lack of hue balance in the reseau rather than for mistakes in lighting. We are using Mole-Richardson arcs, the broadsides and scoops being used without the straw-filter; no filter is used on the camera. Provided, as stated, the negative is correct, printing offers no problems other than the double grading for density and reseau hue.

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APPLICATION OF NON-LINEAR VOLUME CHARACTERISTICS TO DIALOG RECORDING*

J. O. AALBERG AND J. G. STEWART**

Summary.—*The advisability of using a non-linear volume characteristic in dialog recording is discussed. In this connection consideration is given to the following points: (a) the difference of level existing between the original and reproduced speech; (b) the advantages of a system in which manual monitoring can be confined to overall level correction rather than to momentary peaks; (c) the advantage of limiting the range of all except trained voices to assure the highest possible intelligibility. An analysis is then made of the various types of compression possible and a terminology is developed.*

Consideration is given to the type of device most applicable to motion picture recording. The electrical circuits and operating characteristics of a compressor that has been in commercial service for 18 months are discussed. Practical results and advantages obtained by the use of the device during this period are analyzed and the possibility of addition applications is indicated.

At RKO Studios, in 1936, we began investigating a type of annoying volume expansion present in our variable-area dialog recording which, for brevity, we named the "jumps," the difficulty consisting of very sharp volume increases in speech, some cases affecting a single word and at other times a syllable within a word. Upon comparing our product with variable-density recording, we felt that the effect was absent from the latter. At that time there was insufficient variable-area recording available from other studios to permit arriving at a general conclusion; however, we felt that the effect was present in all variable-area recording. Our first observations led us to believe that variable-area recording suffered from inherent volume expansion but extensive tests failed to reveal it.

In the course of our investigation, we found that the average level used by variable-density licensees was such that the high-amplitude peaks, which apparently caused the trouble, were being recorded

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** RKO Radio Studios, Inc., Los Angeles, Calif.

over the non-linear portion of the H&D curve, and were being effectively compressed. In addition, instantaneous peaks of shorter duration than the operating time of the anti-ground-noise bias were receiving further compression. Numerous theater listening tests proved that this type of recording had superior volumetric smoothness.

The desirability of recording dialog with a non-linear volume characteristic becomes apparent on examination of recording and reproducing conditions.

The average level of theater speech reproduction is 15 or 20 db. greater than the original speaking level. In arriving at a proper overall frequency response, this fact is taken into careful consideration, but until now, has not been regarded as important in relation to volume range. At normal speech loudness, that is, at the level at which speech is heard without artificial aid, considerable volume latitude is permissible without annoyance. When this average speech is reproduced some 20 db. higher without compression of momentary peaks, the loudness at these points causes the listener extreme annoyance. This condition is true when the average reproduced level is no greater than is necessary for good intelligibility. Poor reproducer frequency characteristics or high theater reverberation serve to heighten the effect. The energy peaks are not necessarily expressive dynamics used by the actor, but may be caused by lack of breath control or other vocal defects, and the less trained the actor the more noticeable the difficulty. However, the dynamics of even the well trained voice are uncomfortably exaggerated when reproduced at theater loudness. These observations lead to the conclusion that compression of variable-area recording would be desirable.

In the operation of recording equipment, additional advantages accrue from the use of a non-linear volume characteristic. The difficulty of producing a smoothly monitored scene containing good dramatic quality and at the same time confining it within the range necessary to record it on the sound-track is evident. The fact that a compressor will take care of a wide input range makes constant twisting of the gain control unnecessary, and results in a superior product free from improper levels of short duration which can never be corrected.

In considering the characteristics of a device to be used for solving these problems, two distinct types were available:

(*1*) The "limiter."
(*2*) The "compressor" or non-linear amplifier.

The two devices are electrically similar, differing only in operational adjustments. In fact, a single amplifier, by proper adjustment, will perform either function. There is, however, considerable difference in the results obtained with the two types.

To avoid confusion in terminology, the following terms are used in discussing compression characteristics. Two levels must be designated in order to fix the operating limits of such a device:

(*1*) The input level at which compression starts, *i. e.*, the device being linear below this point.

(*2*) The input level at which the compressed output reaches full track or 100 per cent modulation.

Considering the compressed range as starting at the first point and ending at the second, we may speak of compressing so much input within these limits. For example, if compression starts at −10, considering full track to be zero level, and the input must be raised 25 db. before reaching zero level output, then the device compresses 25 db. into 10 db.

The limiter type is designed, as its name indicates, to compress a large input range into a small output range. In the terms outlined above, such a device compresses 10 or 20 db. into 2 or 3 db. When recording with such a device, if the gain is set at a point to permit a reasonable amount of dynamics, the limiter will be actuated only by extremely high input level peaks, and will not assist in smoothing out the average dialog levels. If, on the other hand, the gain is raised to a point where the limiter is being actuated by average dialog levels, the resulting product will have very limited range and will be devoid of desirable dramatics. With the compressor type, non-linearity starts below the point of average dialog level, for example, 10 db. below full track, and compresses 20 or 25 db. into 10 db.

Recordings were made on both types, and the compressor was found superior for motion picture work, one advantage being that the degree of compression remains constant over a large range of input. In other words, the input *vs.* output characteristic of the device consists of a linear portion up to the −10 point, and above that, a straight line of slope less than unity, the slope of the second portion being determined by the amount of compression. This

allows great operating leeway and produces a product of sufficient range but free from disturbing volume peaks. For these reasons, it was preferred and finally adopted at RKO Studios, where it has been in use for eighteen months.

Non-linear amplifier design has been well covered in technical papers and magazine articles. The amplifier in use, however, has the advantage of being adjustable over a wide range of characteristics covering both limiter and non-linear types. Two adjustment controls are used. The first adjusts the fixed bias on the rectifier, which is always biased to or beyond cut-off. This determines the point at which compression starts. With no bias, the amplifier is non-linear over its entire range. As the bias is increased, the starting point is moved progressively to higher levels. The second control adjusts the input signal voltage supplied to the rectifier which determines the slope of the curve above the starting point, *i. e.*, the total amount of compression.

For present conditions of recording, a starting point between 6 and 12 db. below full track, depending upon the recording level in use, has been chosen. This introduces sufficient compression without dangerously reducing the ratio of normal dialog to set noise and reverberation. In setting the second adjustable factor, the total compression, a compromise must be reached between ease of operation and good dynamics in the product. A range of 12 db. in speech seems sufficient for good dynamics, and a setting based upon this range results in satisfactory operating conditions. For our present recording level, this is accomplished by a starting point 10 db. down from full track and the compression of 20 db. into this 10.

The operating time constants of the device are adjustable. Under ideal conditions compression would take place instantaneously, and a sufficient return delay would be used to prevent the device from operating during a full cycle of the lowest recorded frequency. In practice, the compressor is used with an 80-cycle high-pass filter, and the return to normal timing is adjusted to between 25 and 50 milliseconds. If the return is made too rapid, the device oscillates, and if too slow, low-level periods appear immediately after high-level peaks.

When recording with a non-linear volume characteristic, several problems are encountered. Large loudness differences may exist in a compressed signal with small variations in peak amplitude. In the extreme case of the limiter type, scenes having the same peak indica-

tion may vary to the ear as much as 6 db. in loudness. For that reason, reliance must be placed upon aural monitoring, since commercial high-speed visual indicator meters tend to read peak values.

It has been our experience that the compression characteristic of the device tends to reduce the effect of frequency attenuation placed before it. With increasing input level, the frequency output of the channel tends to become flat. It is possible that some advantage may be obtained by splitting the attenuation, placing part before and part after the compressor, to arrive at some balance that will result in a desirable change of frequency characteristic as the level increases. The effect is noticed also as a tendency to compensate for momentary acoustical or electrical peaks regardless of their source and to reduce somewhat variations in quality due to microphone peaks and room reflections.

The device provides additional ground-noise reduction by making it possible to record at higher average modulation without danger of overshooting. Improvement in this direction is attained even though the product may later be re-recorded at a lower level to obtain "Hi-Range" effects.

There are re-recording requirements to which the limiter is better adapted than the compressor type. In scenes where dialog is re-recorded with very high background effects, intelligibility is greatly improved by the use of excessive compression of the dialog. This is best accomplished by the use of the limiter.

Careful observation of our compressed product under a wide variety of theater conditions has shown the absence of the effect that was erroneously regarded as volume expansion, thus making it possible to reproduce the product at higher average levels with a consequent improvement in intelligibility. The occasional error of using excessive dialog compression was evidenced by a lack of proper dynamics in highly dramatic sequences, with resulting loss of screen presence.

While the RKO Studio experience has been confined to the use of this device in variable-area recording, all that has been said seems to apply equally to linear variable-density recording.

DISCUSSION

MR. FRAYNE: I question some of Mr. Aalberg's theses. In regard to the statement that the blasting effect that is present in variable-area recording is absent in variable-density due to the flattening off of the characteristic curve, it

is possible to process variable-density recordings with practically no flattening off of the high modulation if the proper print density is chosen. As you know, it is customary in turning out release prints to vary the density over a very wide range. In doing that I have not observed any evidence that as we go from the flattened out area into the linear area we get this effect. In one Hollywood studio at the present time the compression in speech with the processing they use is of the order of only about 1 db., yet there is no evidence whatever of this blasting.

I have also heard recently some variable-area recordings made with a device other than a galvanometer in which the blasting was not present, so I feel that Mr. Aalberg must be correcting for some fundamental deficiency in the recording device.

MR. KELLOGG: Mr. Frayne states his belief that compression in variable-area recording is needed because of some inherent defect in the equipment that results in an opposite effect or "volume expansion." Messrs. Aalberg and Stewart state in the paper that at first they had the same idea, but on further study gave up the theory. The galvanometer is usually the first device suspected. It has been subjected to the most rigorous tests. Saturation if present in appreciable magnitude, would give some compression, rather than the volume expansion which would have to be compensated by a compressor. Owing to the large ratio of air-gap to iron reluctance, hysteresis produces a negligibly small wave distortion. Hysteresis loss is relatively greater at low levels, as is well known. Measurements on our older galvanometers indicate that it could account for no more than 2 db. loss when the level is 40 db. below full modulation, an amount entirely too small to account for the criticism, and in our newer design this loss has been reduced to 0.5 db. Film-transfer loss has been equally carefully studied, and again we find linearity down to the lowest signals that it is practicable to measure. It was considerations such as these that led the authors of the paper to abandon the theory that there was volume expansion inherent in the system or equipment. Of course almost anything is possible with bad adjustments or processing. For example, with too narrow a zero line and badly fogged prints we can produce volume expansion, but such conditions are the result of outright carelessness, and are clearly not what the authors are talking about.

We come then to the question of whether the speech as it reaches the microphone can often be "jumpy." Of course, it can. We all know hundreds of people who talk that way, and at a little distance, or with some room echoes, they are extremely difficult to understand. When the level is raised above normal, as in theater reproduction, the jumpy effects, as the authors point out, are more noticeable and more annoying.

Turning now to the question of whether the variable-density track affords compression, it is, of course, admitted that so long as the conditions for straight-line or classical variable-density are adhered to, compression does not take place, and the observations that Mr. Frayne mentions are for these conditions. It is my understanding of the paper that the authors believe these conditions to be exceeded in practice so much of the time that a very substantial amount of compression is experienced.

MR. ALBERSHEIM: In experimenting with the variable-area recording method we found, as pointed out by Mr. Kellogg, that variable-area sound-tracks overload more suddenly than variable-density records. It may be that the blasting

occurs only when overload takes place, and is due to the type of harmonics produced by cutting over the edge of a sharply limited sound-track. I have heard some variable-area recordings made at our East Coast laboratories that produced this same sharpness of blasting; at the time I believed it to be due to the generation of disagreeable high harmonics such as are sometimes produced in class *B* amplifiers. Therefore, if one avoids overload or sees to it that the overload distortion takes place gradually, that is, without sharp discontinuities, the blasting will be reduced.

MR. KELLOGG: I would not deny for a moment that overloading, which, of course, frequently occurs in both kinds of records, may accentuate the impression of blasting and jumpy effects. But from what Mr. Stewart and Mr. Aalberg have to say about it, this jumpy quality is not confined to cases where there has been overloading.

MR. FRAYNE: I have seen some oscillograph records of variable-area dialog recently in which a certain amount of this blasting effect had been noticed; and it was quite noticeable that even where the modulation was within 15 db. of the top the blasting was still present. So I do not believe that the overload is entirely responsible for the quality. It is true, of course, that variable-density overload is more gradual than that found in variable-area recording.

MR. KELLOGG: We have made laboratory tests that entirely checked the observations that Mr. Albersheim mentions, namely, that the gradual overloading of variable-density is more tolerable to the ear than overload in a variable-width system. This, plus the fact that it is almost impossible to judge an overloaded density track by eye, would almost inevitably lead to the result that a great deal of overloading is permitted in density tracks. The fact that a true straight-line density track would be as much as 5 db. below a variable-area track in output, but that theaters do not have to make nearly that much adjustment to maintain about equal average loudness, is further evidence of the wide prevalence of overloading. This is not a criticism of the practice of the sound departments using variable-density. Compression has been found definitely to be useful, and they would be foolish not to take advantage of the characteristics of the system up to the point where the benefits from compression are more than offset by the harmful effects of distortion. What Messrs. Aalberg and Stewart say (and we say it, too) is that it is still better to use electronic compression and a track that is not overloaded. To take care of occasional overloads, a more gradual overloading characteristic can be had in the variable-width system by suitably shaping the mask in the recording system.

The authors mention the fact, based upon their tests and observations, that when speech is reproduced at an unnaturally high level, some compression is desirable, which might not be called for if the reproduction were at natural level. Although I do not know whether this relation has been pointed out before, it seems entirely reasonable.

The reasons are probably of two kinds: First, irregular, loud sounds can be irritating and tiresome, although the same sounds, with the same total db. volume range, could be reproduced at lower level without any such irritating effect. In the second place, some compression would undoubtedly be justified in view of the non-linear effects of masking. If loud syllables are quickly followed by weak ones, any reverberation results in difficulty in hearing the weak sounds, and obvi-

ously if, by means of compression, the difference in loudness can be reduced, articulation will be improved. This much is true, regardless of the level of reproduction. The non-linear masking factor, however, results in making matters worse as the level is raised. The loud, voiced vowels which produce the troublesome reverberation are, for the most part, in the range below 1000 cycles, while the mounds that are likely to be lowest are, for the most part, of much higher frequency.

In *Speech and Hearing* (p. 169) Fletcher shows the results of a large number of masking tests. In each group of curves, the frequency of the masking tone is shown above and the frequency of the tone that is masked or drowned out is given on the scale at the bottom of the figure. Taking, for example, a masking tone of 400 cycles, the curves show that the threshold intensity for a 2000-cycle tone is not appreciably affected until the 400-cycle tone has reached 40 db. above its threshold. If the level of the 400-cycle tone is raised from 40 to 60 db., the level of the 2000-cycle tone must be raised 18 db. in order to be audible. Raising the level of the 400-cycle tone 20 db. more, or from 60 to 80, makes it necessary to raise that of the 2000-cycle tone 32 db. to make it again audible; and if the 400-cycle tone is again raised from 80 to 100, the 2000-cycle tone must be raised 28 db. more. Similar effects are shown for masking-tones of 200 and 800 cycles. In view of the measurements just quoted, we should certainly expect that the masking effects of the "hangover" of a loud low-frequency sound would become worse as the levels are raised. This is not saying that the overall articulation will, in general, be impaired by raising the level, for there is an opposing factor, especially where room noise is present and some sounds may be even below threshold. Under such conditions, raising the entire level, of course, improves articulation and it would not be until quite high levels are reached that the loss due to abnormal masking would offset the gain resulting from raising the levels of the fainter sounds. Compression, of course, helps articulation by raising the level of the faint sounds and also by reducing the masking if some reverberation is present.

MR. FRAYNE: Mr. Kellogg's remarks are extremely interesting, but they do not explain to my satisfaction why the effect is found only in variable-area records and not in variable-density records, where, up to the overload point, no considerable degree of compression is noticeable.

MR. AALBERG:* Mr. Frayne's observations are evidently based upon material other than standard studio recordings. Obviously there exists a misunderstanding among the users of variable-density recording systems as to the true magnitude of momentary peaks present in speech recording. Due to the very definite overload point on the variable-area systems, users of this type of track have always been concerned about peak values. We have compared the peak input levels of histrionic speech with simultaneously recorded variable-area and variable-density track output peak levels and found surprising compression in the density system.

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* Communicated.

THE TRANSMISSION OF MOTION PICTURES OVER A COAXIAL CABLE*

HERBERT E. IVES**

Summary.—*The transmission of television signals over wire lines a number of years ago used signals corresponding to images of coarse detail, and required frequency bands accommodated by existing types of circuits. The television images now considered necessary correspond to frequency bands of greatly increased width, and require special wire networks and transmission means.*

The coaxial conductor recently in operation for experimental purposes between New York and Philadelphia can transmit a band of frequencies of approximately 1000 kc. While designed primarily for multiple telephone channels, it offered the possibility of transmitting a single wide band as required for television.

The experiment consisted in providing television-type terminal apparatus for producing signals falling within the available band, and of developing and utilizing methods of transmission that would make most complete use of the frequency band available. For convenience in experimental work, the signals were generated from motion picture film. The film was scanned mechanically by means of a lens disk containing 240 lenses. The film was moved continuously 24 frames per second, and its motion, together with the motion of the lenses in the disk, swept each frame of the film in 240 juxtaposed lines. Light passing through the film was received on a photosensitive surface; the resulting photoelectric current was amplified and by means of modulating and demodulating apparatus transmitted as a single side-band between approximately 150 and 950 kc. At the receiving end the single side-band signal was restored as a signal from zero to 800 kc.

For reception, special cathode-ray tubes were used in which particular attention was paid to the definition of the spot and the linearity of response. Synchronism between the two ends was obtained by sending a single frequency over a separate channel and using it to operate sweep circuits at the receiving end. The use of mechanical scanning and the high-definition receiving tubes resulted in pictures of very satisfactory quality within the limitations set by the frequency band.

The experimental transmission of motion pictures over the coaxial cable between New York and Philadelphia, which was demonstrated in November, 1937, was not primarily an experiment with motion pictures. Motion picture film was used in the experiment as the most convenient means for producing a controllable picture signal, capable

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 20, 1938.

** Bell Telephone Laboratories, New York, N. Y.

of indefinite repetition under identical conditions for test purposes. The test was not planned or carried through with direct reference to the special problems that may be presented by motion pictures as television material, and it is therefore to be expected that many questions that will occur to motion picture engineers will not find their answers in this account of the experiment. Furthermore, it should be made clear that the experiment was, from the standpoint of the communication engineer, one of several whose general purpose was to test the capabilities of the coaxial transmission line for carrying a wide-band signal. In previous tests the possibilities were investigated of providing a very large number of separate telephone channels (some 240 for these tests) each requiring relatively narrow frequency bands. In this test, the problem for study was the possibility of faithfully transmitting signals requiring a single very broad band of frequencies, that is, signals of the television type.

The instrumentalities of the project fall naturally into two groups. One group comprises the terminal apparatus, whose function is the generation of electrical signals from the light coming from the "scene" to be transmitted, and the transformation of the electrical signals, after transmission, back into a satisfactory counterpart of the original scene. The other group comprises the transmission means, and the associated apparatus that puts the signals from the sending end apparatus into form for most efficient transmission, and recovers the signals after transmission in suitable form for use by the receiving end terminal apparatus.

While the two groups of apparatus are different in character, the first being largely optical, the second largely electrical, there is a very close interrelation of requirements and limitations which demanded at the start certain decisions on the character of the picture that it was planned to transmit. These decisions are listed below, with some of the reasons leading to them:

A dominating consideration in this work was to make the most efficient use possible of the frequency band width available in the coaxial cable and associated apparatus. This is essentially an economic consideration, for band width has a definite money cost. The starting point in planning the system is then the frequency band available. Without going into the considerations that determined the characteristics of this particular coaxial cable, it suffices here to state that the upper limit of frequency satisfactorily handled by the cable and its associated repeaters was about 1000 kc. This does not

mean, however, that television signals occupying a band from 0 to 1000 kc. can be accepted for transmission. The first difficulty encountered is that immunity from external disturbance, which is characteristic of the coaxial structure, does not extend to the lowest frequencies. These are, however, an essential part of the television signal. Recourse must therefore be made to the use of a "carrier" frequency which lifts the whole frequency band to be transmitted to a higher value. When this is done, by the methods commonly used

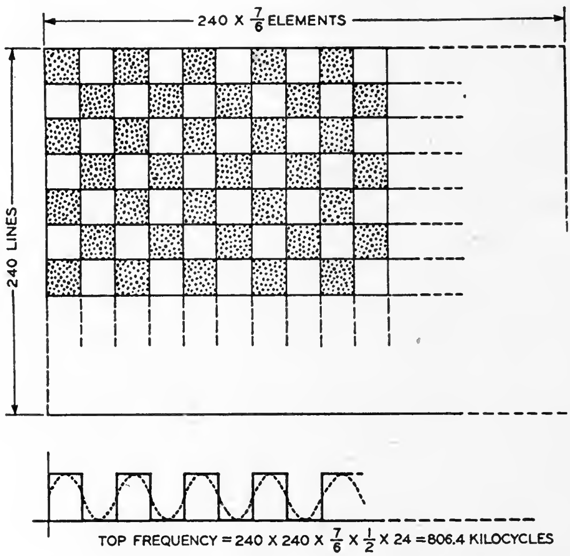

FIG. 1. Relation between picture elements, frame repetition frequency, and band width for transmission.

in radio the signal is transmitted as two "side-bands," one to each side of the carrier, each occupying the entire frequency band space of the original signal. If this double-side-band method were used with our coaxial cable it would mean that our signal band would have to be less than half of the 1000 kc. or 500 kc. in width.

This factor of $^1/_2$ would mean a very serious loss, to be avoided if possible. A method of avoiding this loss, at the same time utilizing the carrier method of placing signals at a desired place in the frequency band is offered by "single-side-band transmission." This method, as utilized in this experiment, places the single side-band

between approximately 120 and 950 kc., thus furnishing a useful frequency band of over 800 kc.

Taking this frequency band as a starting point we can determine, by calculations that are now conventional in connection with image transmission, the number of scanning lines to use in our image analysis. One variable in this calculation is the number of image repetitions per second. With our choice of motion picture film as our source of images, this repetition frequency is most conveniently taken as the standard frame frequency of 24 per second. Another variable is the shape of the picture, or frame. This was chosen close to the 4:3 ratio of dimensions common in film; actually, because of space clearances needed in the apparatus, with scanning in the long direction of the rectangle, the ratio finally used was 7:6. Using these figures we arrive at the number of scanning lines to utilize the available frequency band as follows: the number of picture elements, assumed square, to fill the 7:6 area will be the product of n (the number of scanning lines) by $^7/_6 n$, by f (the repetition frequency). Now, a single signal cycle consists of an alternation of light and dark, which may be considered as two picture elements, as illustrated in Fig. 1. We therefore have, if we call the top frequency F,

$$F = {}^1/_2 \times n \times {}^7/_6 n \times 24$$

Taking F as 800 kc., this gives us for n very approximately 240. On the basis of these considerations, therefore, a choice of 240 scanning lines was indicated as the upper limit capable of use with the transmission line.

In the early stages of the work, and paralleling the coaxial cable development, a study of the relation between picture quality and the size of picture elements was made using motion picture films printed out of focus. By correlating the known size of the circle of confusion in these films with the size of the elements in a television image, with reasonable allowances for the effects of the differences in image structure, it appeared that a 240-line image should be capable of giving a picture not seriously inferior in quality to the average small home motion picture projector, provided comparable freedom from visible image structure were obtainable, with comparable contrast and fidelity of tone rendering.

The use of 240-line scanning, with 24 frames per second, as decided upon for this experiment, deviates considerably from the figures of 441 lines, and 60 (interlaced) frames per second, which are now

being contemplated as "standard" for television. It was, however, believed that the principal questions presented by the problem of transmitting television signals could be satisfactorily answered by this study, and that the wider frequency bands demanded by the newer television standards can be handled by more or less straightforward extensions of the means here used.

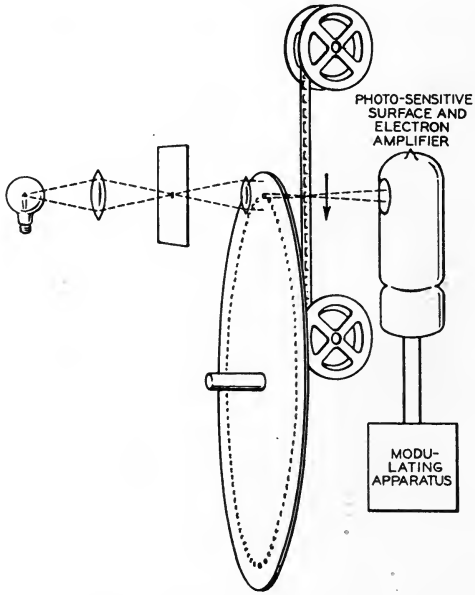

FIG. 2. Diagrammatic representation of optical system.

Signal Generating Apparatus.—The scanning apparatus chosen for this test was of the simplest type, namely, a scanning disk. The disk was made from a saw blank 6 feet in diameter; near the periphery of which were mounted, at identical radial distances, 240 lenses, each consisting of a pair of plano-convex elements. The focal length of the compound lenses was approximately 1 inch, and the diameter ultimately used was about $^3/_8$ of an inch.

A schematic diagram of the optical system used is given in Fig. 2, while Fig. 3 shows a photograph of the disk housing with the film-driving mechanism at the top. The light-source was a ribbon-filament tungsten lamp, operated on direct current, which was

imaged by means of a condensing lens upon a square aperture. This aperture was at the focus of a collimating lens past which the lenses in the disk moved. Each disk lens formed a sharp image of the aperture and, as the disk rotated, this image was moved across the film at the focus of the lens. The film was moving continuously so that successive lens images scanned successive lines on the film. In

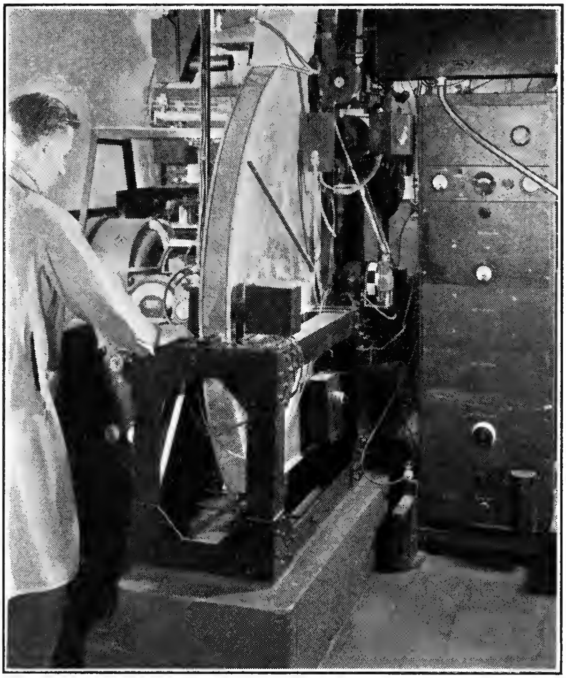

FIG. 3. Scanning disk used for generating signals from motion picture film.

order to carry the light after transmission through the film to the photosensitive surface, a light-tunnel was used consisting of a rectangular bar of highly transparent material (*Pontalite*) in which, through multiple total reflection, the light was caused to emerge at the far end with uniform intensity from all positions of the scanning lenses.

On emerging from the light-tunnel the light falls upon a photoelectrically sensitive surface, which is the first element of a 10-stage electron multiplier. The signal delivered by this device had a peak

value of 100 microamperes and is strictly proportional to light-intensity.

For purposes of local test, before connecting this terminal apparatus to the coaxial transmission system, a wide-band amplifier was

FIG. 4. Cathode-ray tube used for reception of television images.

used, with a range from 5 cycles per second to 1,000,000 cycles. In conjunction with this, in order to supply an equivalent for the direct current not transmitted, a "zero wander" current was introduced, which automatically brings the black at the end of each scanning line to a constant value.

Besides the picture signal, the sending end apparatus must supply signals for synchronizing the sending and receiving ends. These were generated optically, using the same lenses as for the picture signals. Light flashes were produced from an auxiliary light-source, whose image was swept over a small slit. The brief light flashes (about 3 microseconds in duration) fall upon a second electron multiplier, the output of which is amplified to give pulses which trip a gas-filled tube and yield a saw-tooth wave. This saw-tooth wave is used in the local testing to control the sweep circuits of the cathode-ray receiving tube. For transmission purposes the saw-tooth wave is filtered to produce a 5760-cycle sine wave. This frequency is transmitted by the carrier equipment to the distant end, and there pulses are produced to control sweep circuits in the receiving apparatus. The sine wave produced by the light flashes was used also

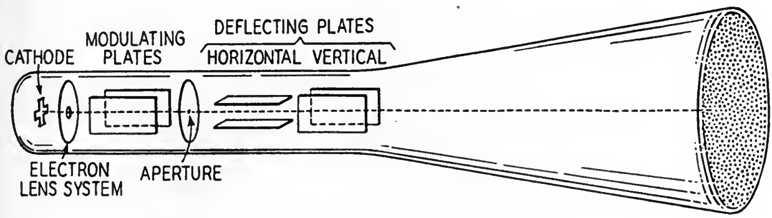

FIG. 5. Construction of cathode-ray tube.

to beat with the output of a 5760-cycle precision tuning fork, to actuate a speed-control circuit by means of which the speed of the d-c. motor used to drive the disk could be held constant to one part in 5000.

Receiving-End Apparatus.—The receiving device chosen was the cathode-ray tube, and a special precision type was designed for this test by Dr. C. J. Davisson, attention being directed to the construction of a tube that should give the highest possible fidelity of detail and tone rendering, quite irrespective of cost and of considerations that might enter were commercial production contemplated.

The special features of the tube that contributed to its excellence as a testing tool are best brought out by a description of its essential elements. Fig. 4 is a photograph of the tube and Fig. 5 is a schematic diagram of its construction. It was made of very considerable length (5 feet) in comparison to the size of the field (7 × 8 inch), in order to minimize distortion. The deflection of the beam was controlled in

both directions electrostatically. In order to provide a sharply defined rectangular spot whose dimensions across the scanning line should not change, an electron lens system is provided that forms a narrow beam of electrons from a hot filament onto an aperture 0.006 inch square. Between the lenses and the aperture are two modulating plates (actually two cross-connected plates to insure parallel displacement of the beam without any angular component)

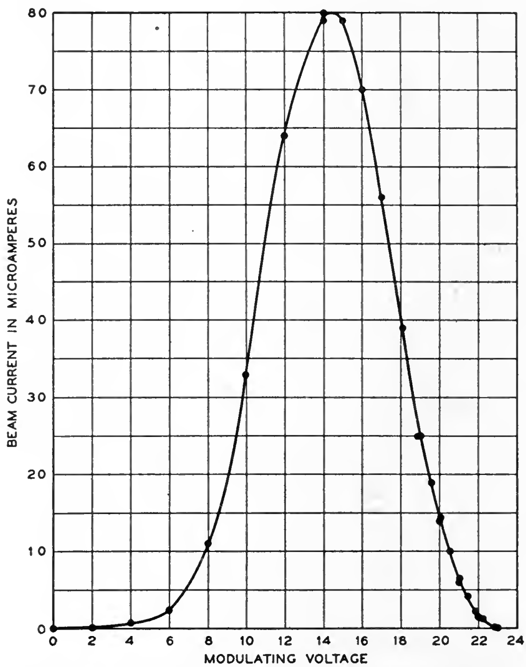

FIG. 6. Characteristic of special cathode-ray tube.

connected to the incoming circuit in such a way that the potentials of the plates vary according to the strength of the incoming signals. The electron beam is thus deflected so that more or less of it passes through the aperture and thence to the fluorescent screen on the front of the tube. The spot of light on the screen is consequently a rectangle, of constant height corresponding to the separation of the scanning lines, but of variable width in the direction that the spot is to be moved in scanning. When swept across the screen these spots of constant height produce lines of light, which, with accurate sweep

control to juxtapose the lines, result in a very uniform structureless field. The light from the variable-sized spot should vary linearly with the strength of the signal for faithful reproduction of tone values. In Fig. 6 is shown the characteristic actually obtained on a representative tube. This shows the variation of beam current through the final aperture, to which the light from the fluorescent screen is closely proportional, as a function of the modulating voltage. The mechanical line-up of the electron lens elements is in this case such that the voltage corresponding to the accurate centering of the spot on the aperture is not zero as in the description above but about 14, which is taken care of by a biasing potential on the tube. Depending upon the polarity of the signals, either slope of the characteristic can be used; often one side will be definitely better than the other.

In order to produce a picture the spot on the fluorescent screen must be swept over the face of the tube so as to scan the whole rectangular area of 7×8 inches in $^1/_{24}$ of a second. This sweeping operation is performed by applying "saw-tooth" signals, derived from the synchronizing pulses, to two other pairs of plates, at right angles to each other between the aperture above described, and the fluorescent screen. The potential of one of these sets of plates is controlled at a periodicity of 5760 times per second, and sweeps the beam of electrons across the screen from one side to the other in exactly the same time that the spot of light from the sending-end lens disk traverses the film. At the end of the sweep the beam is quickly returned to its initial position (by the vertical element of the saw-tooth), the signal being reduced to zero during this period by masking the edge of the film at the sending end. The potential of the other pair of plates is controlled at a periodicity of 24 times per second, which is the rate of scanning successive frames. These plates, being at right angles to the others, deflect the electron beam downward at the same relative speed as the film is moving at the sending end. This results in the passage of the spot on the fluorescent screen in lines successively displaced by the vertical height of the spot. After the last line has been scanned the spot returns quickly to the top of the tube, and a properly timed negative impulse superimposed upon the signal reduces its intensity during this travel so as to render the spot invisible.

Due to the accurate definition of the spot on the fluorescent screen and the freedom from distortion, the bright rectangular field produced

corresponding to clear film is of a high degree of uniformity and freedom from visible structure, which permits close inspection of the received image. Because of the close approximation to a rectilinear relation between the signal (itself accurately proportional to the transmission of the film) and the brightness of the scanning spot, a high degree of fidelity of tone rendering is obtained. Pictures produced by directly coupling the sending and receiving apparatus were gratifyingly close in appearance to motion pictures directly projected to the same size.

TRANSMISSION OF TELEVISION SIGNALS OVER THE COAXIAL CABLE*

Given the satisfactory performance of the signal-generating and signal-recovery apparatus, when directly connected to each other,

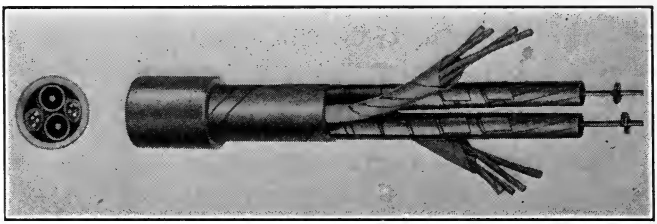

Fig. 7. Coaxial cable.

the task of a transmission system is to reproduce this satisfactory performance with the sending and receiving apparatus separated from each other by any desired distance. For this to be possible the transmission medium must to a high degree be immune to interference from extraneous sources of electrical energy; it must be capable of transmitting the wide frequency bands involved, without discrimination between frequencies; and it must be possible to insure that all frequencies are transmitted at the same speed. Failure to meet any of these requirements will cause serious distortions in the received picture.

The coaxial cable, shown dissected in Fig. 7, consists essentially of a wire supported by insulators in the middle of a conducting tube.

* A more extended account of the transmission features is given in *Electrical Engineering* (June, 1938), by M. E. Strieby who was directly responsible for this phase of the development.

Due to the "skin-effect" high-frequency signal currents are carried largely in the outer skin of the central conductor and along the inner surface of the outer conductor. Currents caused by high-frequency external interference flow substantially on the outer surface of the outer conductor, and are therefore electrically separated from the signal currents by the intermediate metal of the outer conductor. Because of this protection from outside interference it is possible to

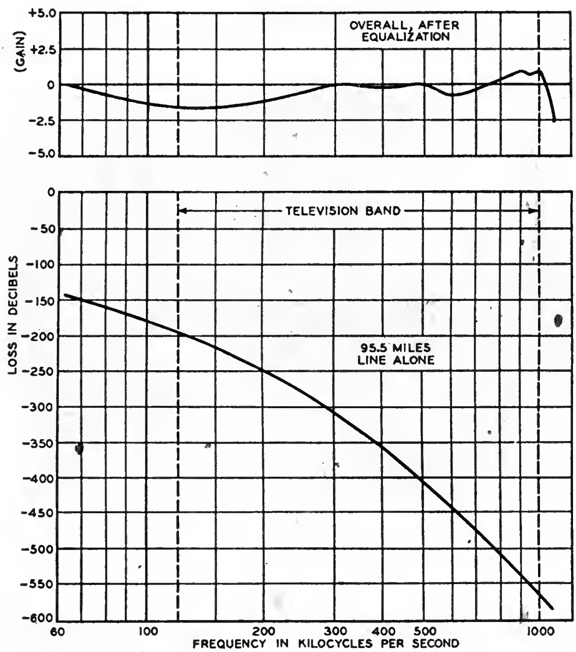

FIG. 8. Attenuation of signal strength in coaxial cable.

subject the signals to an enormous amplification, and so offset the very considerable attenuation of signal strength owing to transmission losses.

The attenuation of signal strength in the 95 miles of cable between New York and Philadelphia is shown in Fig. 8; it increases with frequency to a maximum of about 600 db. at 1000 kc. To compensate for this loss, repeaters are placed in the line at intervals of 10 miles. These repeaters are designed with proper attenuation equalizers so as to amplify the low frequencies less than the high, giving a final

very flat transmission characteristic over the entire frequency range, as shown in the upper diagram of Fig. 8. A photograph of an actual two-way repeater and power supply is shown in Fig. 9.

A characteristic of wire transmission is the distortion caused by different times of transmission for different frequencies; the lower frequencies lagging behind the higher. In order that the picture details will appear in the same relative position in the reproduced as in the scanned picture, all frequencies must be received in closely the same time relationship in which they were generated. To assure this, delay networks were introduced to equalize the transmission

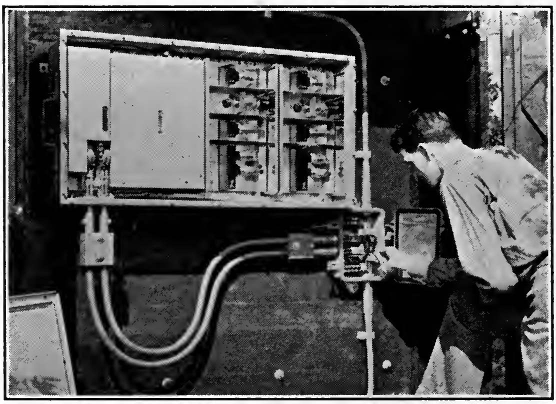

FIG. 9. Repeater and power supply used on coaxial cable.

speeds over the whole frequency range. The phase delay in the coaxial circuit as a function of frequency is shown in Fig. 10, and in the upper diagram a measured performance characteristic after the delay equalization.

As discussed earlier the coaxial cable does not offer sufficient shielding for very low frequencies, so that the original television signals must be translated upward in the frequency spectrum before transmission in order to raise them above the region of disturbance. The most efficient use of the frequency band available is obtained by using only one of the two side-bands normally produced in this translating process. In order to place the translated signal in the most advantageous frequency position, a double-modulation process was used which can be followed with the help of Fig. 11, in which are

shown the two modulating steps at the sending end and the two demodulating steps at the receiving end in four lines beginning at the top. A carrier of 2376 kc. is used for the first modulation, which results in a lower side-band from 1570 to 2376 kc. and an upper side-band from 2376 to 3182 kc. The carrier itself is eliminated in the balanced modulator. The output of this modulation is passed through a filter, but because the two side-bands touch each other at 2376 kc., the filter can not be designed to cut off all the upper side-

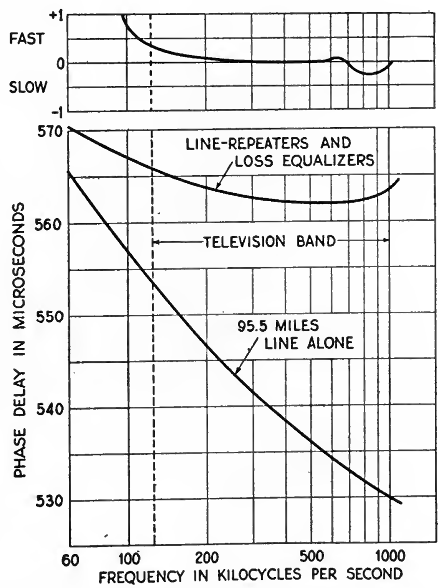

FIG. 10. Phase delay in coaxial circuit.

band. At the output of the filter there is thus the lower side-band plus a small amount of the lower part of the upper side-band. The upper side-bands from all subsequent modulations are readily eliminated by the filters which follow because of the wide separation.

The carrier for the second modulation is 2520 kc., and the lower side-band extends from 950 down to 144 kc. and for a vestigial range below 144 kc. equal to the width of the side-band remaining from the first modulation. The high-pass filter following this modulation is accurately designed to pass with controlled attenuation not only a group of frequencies just above 144 kc. but also the vestigial side-band, which extends from 144 to about 120 kc. The resulting signal

extending from 120 to 950 kc., is then passed over the coaxial cable to Philadelphia.

Here the transmitted band, after first passing another high-pass filter, is applied to the first demodulator, together with a carrier of 2520 kc.; and the lower side-band, from 2400 down to 1570 kc., is passed to the second demodulator where a carrier of 2376 kc. is applied. The lowest frequency of the lower side-band, 1570 kc., is converted to 806 kc., becoming the highest frequency of the final

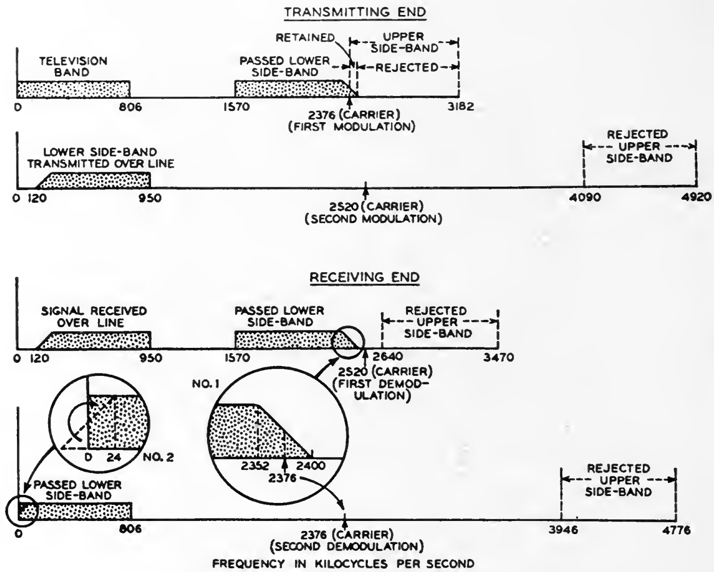

Fig. 11. Modulation processes used in transmitting broad frequency band over coaxial cable.

demodulated band. The frequencies from 2352 to 2400 kc. of the side-band entering the second demodulation had been attenuated somewhat by the high-pass filters following the second modulator at the sending end and preceding the first demodulator at the receiving end; and the second demodulating carrier, 2376 kc., falls in the middle of this attenuated band as shown in inset No. 1. Frequencies extending about 24 kc. above the carrier are inverted by the demodulation, and superimposed upon the corresponding frequencies just below the carrier. The magnitude and phase of these components are proportioned by the high-pass filters and an equalizer so

that the overall result, when they are superimposed, is an essentially flat transmission band from 0 to 806 kc.

The terminal equipment, besides providing modulators, amplifiers, filters, and equalizers, must provide also for the generation of the two modulating carriers accurately spaced. This is accomplished by deriving all carriers from a 4000-cycle reference frequency at the transmitting end. From this source a 72-kc. frequency is first obtained, and is then used for deriving the modulating carriers of 2376 and 2520 kc. through harmonic generators. The same 72-kc. frequency is also transmitted over the coaxial line to Philadelphia, where exactly synchronous carriers are derived from it for demodulating.

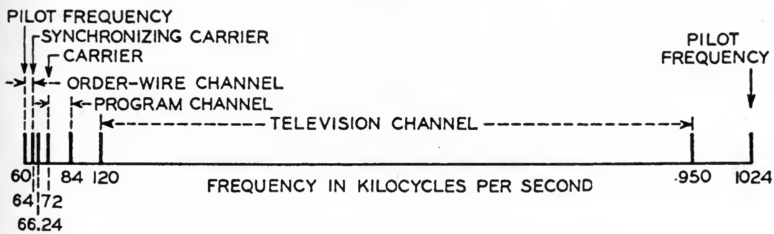

FIG. 12. Utilization of frequency band available.

Picture synchronization at the two ends is provided by transmitting a simple sine-wave signal derived from the sending-end scanning disk as previously described. This is used to generate saw-tooth sweep impulses for the receiving end cathode-ray tube. The 5760-cycle synchronizing frequency produced by the disk is modulated with the 72-kc. carrier frequency and transmitted as a single frequency of 66.24 kc. to Philadelphia, where it is demodulated with the same 72-kc. carrier to recover the original 5760-cycle synchronizing frequency.

A program channel from 72 kc. to 84 kc. is also provided in the cable to accommodate the sound accompanying the motion picture signal, and finally frequency space is provided for an order-wire talking channel from 60 kc. to 64 kc. and two pilot frequencies at the extreme ends of the transmitted band, namely, 60 kc. and 1024 kc. for automatically maintaining a constant overall transmission level.

The total television transmission band is indicated diagrammatically in Fig. 12 which shows that of the total transmitted band of

$1024 - 60 = 964$ kc., the actually useful part is approximately 820 kc. or 85 per cent.

The terminal apparatus and the coaxial line, as above described, were used in a series of demonstrations to interested experts, the motion picture film passing through the apparatus in New York producing motion pictures in Philadelphia. It was the generally expressed opinion that the pictures seen in Philadelphia were substantially the same as those produced by the directly connected terminal apparatus in New York. On critical examination some transients and faint ghosts were detectable in the Philadelphia picture. These, however, were comparable with similar defects on the monitoring receiver at the sending end, traceable to known characteristics of the modulating apparatus capable of improvement; hence are not chargeable to the cable system and once located are capable of elimination. The experiments have proved that a wide band signal of the type required for television can be satisfactorily transmitted over a coaxial system. Work is now under way on repeaters and terminal apparatus for transmitting wider bands of frequency to meet the standards now being attempted in television.

MAINTENANCE OF A DEVELOPER BY CONTINUOUS REPLENISHMENT*

R. M. EVANS**

Summary.—*By a series of simple assumptions that do not appreciably depart from current practice, it is shown that it is possible to calculate readily the concentration of any ingredient present in a continuously replenished developer solution during use. The equations for the equilibria and rates of growth of the various substances are derived, and applied to a practical case. The benefits of chemical analyses for developer constituents both for maintenance of quality and for economy are pointed out. The analytical methods published by Lehmann and Tausch are outlined briefly.*

In handling motion picture film on continuous processing machines, or roll films on intermittent machines, it becomes essential that the developer should always have the same properties, not only from hour to hour but from month to month. This is true largely because it is not economically practicable to vary the time of development to any great extent, or to alter the amount of exposure given the material in order to compensate for changes in developing power. A single reel of motion picture negative may be printed from three to five hundred times over a period of a week or more and then be printed spasmodically as orders are received over a period of years. To change the printing exposures from day to day would be much more costly than proper maintenance of the bath. Variation in the bath also would not permit the maintenance of consistent quality.

Accordingly, the larger motion picture laboratories are confronted with the problem of maintaining their developers at a constant level at all times. Since, from the nature of the problem, replenishing must be continuous, it is apparent that the situation is relatively complex. It is possible, however, to reduce the problem to a relatively simple mathematical equation and deduce from this certain important rules for procedure. Because of the lack of previous literature on the subject the following discussion is relatively complete.

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 20, 1938. Communication No. *673* from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

It should be stated at the outset that nothing short of complete running chemical analyses of the solutions and a frequently modified replenishing formula is possible for a *complete* solution of the problem. These extremes are seldom necessary because of the variations that may be permitted and the possibility of photographic tests. To the writer's knowledge such chemical analyses are not at the present time being carried out in any of the major laboratories, although the importance of the problem and the possibilities for economy would seem to make them distinctly desirable.

Maintaining a solution constant involves correcting for variations caused both by air and by silver halide. Both these are oxidizing agents and their effect varies to some extent with the nature of the developing agent. Lehmann and Tausch[1,2,3,4] have shown that when an alkaline mixture of elon and hydroquinone is oxidized by air, only the hydroquinone reacts. Only after the hydroquinone is nearly used up does elon take any appreciable part in the reaction. The chief product of the oxidation is hydroquinone monosulfonate, which is formed according to the following equation.

$$C_6H_4(OH)_2 + O_2 + 2Na_2SO_3 = C_6H_3(OH)_2.SO_3Na + Na_2SO_4 + NaOH$$

The equation for elon is the same except that elon monosulfonate is formed. A small percentage of the oxidized developer does not form the monosulfonate but passes on to more complex structures. The end-product of this small percentage is a brown compound or mixture of compounds of the humic acid type. It is this portion of the oxidation products that causes the familiar stain of severely exhausted developers. It appears that not more than 5 per cent of the oxidized developing agent passes into this form.

When an *MQ* developer is oxidized by silver bromide, however, as it is in the normal process of developing an image, it is not the hydroquinone but the elon that plays the more important role. Under most conditions there is probably a considerable amount of hydroquinone also oxidized *simultaneously*. The equation is

$$C_6H_4(OH)_2 + 2\ AgBr + Na_2SO_3 = C_6H_3(OH)_2.SO_3Na + 2Ag + NaBr + HBr$$

for hydroquinone and a similar equation exists for elon.

Extended oxidation by air or silver bromide will produce considerable quantities of the disulfonates of both hydroquinone and elon but since such badly oxidized solutions are not in use they need not be discussed here.

Elon monosulfonate may be used as a developing agent, as was pointed out by Tausch, and hydroquinone sulfonate as a developer has been known for many years. Both these compounds, however, are very weak in their action and their presence in an *MQ* developer in small quantities produces no appreciable change in the bath. To the extent that these compounds form in any given solution, they may be considered simply as so much hydroquinone or elon removed. Some of the other products formed are not at all negligible and are considered below in detail.

The present discussion will be restricted to elon-hydroquinone developers that have in their original formulas only sulfite, alkaline salts, and soluble halides, in addition to the developing agents themselves. In order to generalize the problem the specific nature of the alkali will not be assumed.

Accordingly, in a fresh batch of developer solution there are present,

(*1*) Elon
(*2*) Hydroquinone
(*3*) Sodium sulfite
(*4*) Alkaline salts
(*5*) Soluble bromide (usually potassium)

Oxidation of this solution by air will produce

(*6*) Hydroquinone monosulfonate
(*7*) Sodium sulfate
(*8*) Free hydroxide (NaOH)
(*9*) Staining developer by-products

Oxidation by silver bromide emulsions (which always contain a small percentage of silver iodide) will produce in addition

(*10*) More soluble bromide
(*11*) Soluble iodide up to equilibrium with the film
(*12*) Elon monosulfonate
(*13*) Slight traces of elon and hydroquinone disulfonates
(*14*) Free acid (*HBr*)
(*15*) Temporary (up to a few hours after use) concentrations of unreduced dissolved silver complexes.

The alkaline water solution will produce

(*17*) Dissolved gelatin
(*18*) Probable degradation products of gelatin

In addition there will be a gradual accumulation of substances present in the emulsion of the film that dissolve out into the developer. Such substances are sensitizing dyes (in negative materials), more soluble bromide, *etc.* Dirt, calcium carbonate, and extraneous matter will also enter the tanks either on the film or in the water and there are probably small amounts of other substances produced by chemical reactions of which there is at present no knowledge.

The problem of replenishing such a solution is two-fold. Starting with fresh solution the bath must be brought to a state of dynamic equilibrium with film, air, and replenisher, without permitting the photographic properties to change appreciably. This equilibrium must then be maintained in the face of changing conditions and, in general, with only the replenisher as an independent variable, since film and air quantities can not be varied at will. In a large industrial laboratory the amount of solution in the machines may approximate 10,000 gallons and the amount of film to be processed may be from five to ten million feet of motion picture positive per week. Correspondingly lower figures hold for negative handling.

It is customary to connect batteries of developing machines by a system of piping in such a way that all the developer may be made to circulate past a single point. The volume of the solution is, of course, held constant.

Dry film passes into the developer at a constant rate during the operation of a machine and carries with it a small amount of air, both on its surfaces and in the perforations. The latent image on this film enables the developer to reduce to metallic silver a quantity of silver halide that varies widely, depending upon the nature of the subject matter. Motion picture positive film contains per thousand feet, roughly fifty grams of metallic silver in the form of halide salts. Of this, amounts varying from practically none up to nearly the full amount may be developed, depending upon the subject of the reel. Thus, sound-track or black titles on a clear ground may represent only a few grams of silver per thousand feet, while a reel consisting largely of night scenes and the like may represent forty grams or more of reduced silver. On the average, approximately one quarter of the silver is ordinarily utilized or from 10 to 15 grams. The remainder may be recovered by an efficient hypo recovery system. With respect to a given developing machine, however, the total average amount of silver reduced per day is not constant unless care is taken to vary the type of work being handled. With an efficient

circulating system, good mixing, and several developing machines operating simultaneously, satisfactory averaging of the work on all machines is possible.

The wet film after development passes out of the developing solution into the rinse water, carrying with it a considerable quantity of the solution. This quantity varies with the speed of the film, the design of the machine and the efficiency of such devices as may be present to prevent "carry over." If the surface of the film carries no surplus layer of liquid there is in the gelatin of motion picture positive approximately one quart of solution per thousand feet. High speed and absence of devices to remove the surface layer may triple this figure. This solution loss, then, represents a definite *minimum* quantity of liquid that *must* be added to the system as a whole to maintain its volume constant. This quantity frequently is insufficient and more must be bled away so that the desired amount of replenisher may be introduced without overflowing the tanks.

Since there is seldom occasion to refill such a system completely with entirely fresh solutions, the dynamic equilibrium that must be maintained after aging will be considered first. Since fresh replenisher is constantly entering the system, and developer that has nearly the photographic properties of the bath as a whole is constantly leaving the system, considerable economy can be effected by choosing the proper position for the point on the system at which the two occur. They should be so situated that the "bleed" by which solution is removed occurs in the system just before the point at which the replenisher enters the system. Theoretically, some economy could be effected also by having the fresher developer at the end of the machine into which dry film is being fed and the more exhausted developer removed from the other end. This sets up an unstable balance, however, which breaks down when the machine is stopped and so leads to variations over which there is little control.

If the system is so designed that perfect mixing may be assumed at all times, an equation may be written for the growth or decrease of any constituent of the solution. For convenience in computation, the figures will be given in the metric system for 10,000 gallons of developer replenished at a rate of $2^1/_2$ gallons per minute. If:

b = replenisher rate in liters per minute = bleed rate
v = total volume of the system in liters
a' = initial total amount of a given substance

x' = amount of the given substance at time t
k' = amount of the substance added per minute

then $$k'dt - \frac{b}{v}x'dt = dx' \text{ or } dt = \frac{dx'}{k' - \frac{b}{v}x'}$$

this equation has as a solution

$$t = \frac{v}{b}\log_e \frac{\left(k' - \frac{b}{v}a'\right)}{\left(k' - \frac{b}{v}x'\right)} \text{ or } \frac{b}{v}x' = k' - \left(k' - \frac{b}{v}a'\right)e^{-\frac{b}{v}t}$$

A rather obvious axiom which greatly simplifies the calculations may be stated as follows. *A substance that is being formed in the solution at a constant rate may be considered as being introduced in the replenisher.* Since material is also *actually* added in the replenisher, it is convenient to convert the above equation to *concentrations* rather than *amounts*. Set

$k = \frac{k'}{b}$ = concentration of material in replenisher
$a = \frac{a'}{v}$ = initial concentration of the material in the system
$x = \frac{x'}{v}$ = concentration of the material in system at time t

The equation may now be converted to these variables, giving, as a final solution,

$$x = k - (k - a)e^{-\frac{bt}{v}}$$

This equation holds for the growth of the concentration of any substance in the solution whether the initial value is zero or finite. An example will make its application clear. If the initial concentration of potassium bromide is assumed to be one gram per liter then $a = 1$. Other figures may be assumed as follows:

b = 10 liters per minute
v = 40,000 liters

If several high-speed developing machines are all in operation on the system the amount of film developed may be 1000 feet per minute. From this quantity of film we may expect that bromide in amount equivalent to about 15 grams of silver will be released. This is roughly the equivalent of 15 grams per minute of potassium bromide. Since complete mixing has been assumed, this amount may be con-

sidered for convenience as entering in the replenisher, which of itself would contain none. This gives $k = 1.5$ g./liter of replenisher solution per minute.

The equation for x, the concentration of bromide in the bath as a whole at time t, becomes:

$$x = 1.5 - (1.5 - 1)e^{-\frac{10}{40{,}000}t}$$

or

$$x = 1.5 - 0.5e^{-\frac{t}{4000}}$$

Since such a system if operated long enough will come to equilibrium at a constant concentration of bromide, it is of interest to determine what this equilibrium concentration is. Substituting $t = \infty$ it is seen that the last part of the expression becomes zero and $x = 1.5$ grams per liter of potassium bromide. That is, the bromide has increased to the concentration calculated above by dividing the amount formed per minute by the number of liters per minute of replenisher added. This illustrates the fact that *the equilibrium concentration of all ingredients except those used up in the process (developing agents and sulfite) tends to become equal to that of the replenisher solution.*

It is instructive to consider the time taken to attain this equilibrium. Because in theory the limit is approached exponentially it is possible to determine only the time required to attain a given percentage. For practical purposes 1.45 grams per liter of bromide is certainly indistinguishable from 1.50. To find the time required to reach this value (97 per cent of equilibrium) it is convenient to rewrite the equation so that it gives t in terms of x. That is:

$$t = \left(\frac{v}{b}\right) \log_e \frac{(k - a)}{(k - x)} = \frac{2.3v}{b} \log_{10} \frac{(k - a)}{(k - x)}$$

Under the above conditions then

$$t = \left[\frac{(2.3)(40{,}000)}{10}\right] \cdot \log_{10} \frac{(1.5 - 1)}{(1.5 - 1.45)}$$

and $t = 9200$ minutes or a little more than six days of continuous operation.

The mixing in the above example has been assumed perfect. In general, if the inlets and outlets are properly placed, the time taken would tend to be less than the above rather than more. If there is a considerable amount of liquid carried over by the film it may be assumed that this liquid is somewhat richer in bromide than the solu-

tion in general. In this case the amount of bromide removed per minute is greater than that assumed and the *equilibrium* concentration is somewhat less. The time taken to reach the same *percentage* of equilibrium remains the same.

An exception was made in the application of these equations to calculations of the developer and the sulfite that are being exhausted. If the replenisher is so *increased* in the concentration of these ingredients (above that used in the fresh mix) that the amount used up is exactly equal to the amount added there will obviously be no change. If under the above conditions 15 grams of silver are reduced, then from the equation for the chemical reaction given earlier, the amount of developer used up would be approximately 7 grams if it were all hydroquinone and 12 grams if it were all elon (one mol of developer reduces two mols of silver bromide). In a positive type of developer, we may assume that approximately ten times as much elon reacts as does hydroquinone, although this figure must be determined for every formula and for every developing time. If this figure is assumed, then 0.63 gram of hydroquinone and 10.9 grams of elon are used up per minute. These amounts must be supplied by the replenisher. If the rate of supply of the replenisher is 10 liters per minute, then 0.063 gram per liter of hydroquinone and 1.09 grams per liter of elon must be present *in addition* to the amount present in the regular formula. By the same reasoning 0.8 gram per liter of anhydrous sodium sulfite is needed but such a small amount may be neglected.

The foregoing calculations do not include the effect of air upon the solution. It has been shown that this affects only the hydroquinone and the sulfite and it obviously depends to a very large extent upon the system itself. Variable sources of air are the pumps, the speed of the film, the free air surfaces, *etc.* If it is assumed, for illustration, that the entire system absorbs and reacts with the oxygen in *one* cubic foot of air per minute, then the hydroquinone equivalent of this oxygen equals 27.2 grams per minute (760 mm. pressure and 20°C). The sulfite equivalent is roughly 62 grams. Replenishing at the rate of ten liters per minute, therefore, it would be necessary to add 2.7 grams of hydroquinone and 6.2 grams per liter of sulfite in addition to the amount necessary to compensate for development of the films. Note that this is for only one cubic foot of air absorbed per minute in a ten thousand gallon system. Figures that would show the true extent of aerial oxidation in such a system are not

available. It is apparent, however, that it is economical to go to some lengths to reduce aeration of the solution.

Digressing for a moment it should be noted that the Lehmann and Tausch equations quoted[1,2,3,4] above indicate a way in which the actual air absorption may readily be measured. Sodium sulfate is formed only during aerial oxidation. This product does not appear when silver halide is the oxidizing agent. After a bath has been in operation for some time and has come to equilibrium with respect to this sulfate a simple analysis will give its concentration in grams per liter. By the reasoning used above, this quantity multiplied by the replenisher rate in liters per minute gives the average amount of sulfate produced per minute by the air. One mol of O_2 produces one mol of sodium sulfate to a good first approximation. Since the ratio of the molecular weights is roughly 4.5, the grams per minute of sulfate divided by this figure gives grams of O_2 per minute. One cubic-foot of air at 760 mm. pressure and 20°C contains 7.9 grams of O_2. Hence, the grams of oxygen per minute divided by 7.9 gives the number of cubic-feet of air absorbed per minute. The importance of obtaining this figure in such a way that is is accurately averaged over a considerable length of time is obvious.

The equilibrium concentration of any ingredient as well as its concentration at any time after the start of the system may be calculated by the methods already outlined. If the initial concentration a of a compound is zero, as in the case of the sulfate, for example, the equations are simplified to

$$x = k\left(1 - e^{-\frac{bt}{v}}\right)$$

and

$$t = \frac{2.3v}{b} \log_{10}\left(\frac{k}{k - x}\right)$$

where the letters have the same significance as before. The time taken to reach 90 per cent of the equilibrium concentration does not change since it depends only upon the ratio b/v, of replenisher to total volume.

It is now possible to consider the problem of starting with a fresh bath and bringing it to equilibrium without serious change in its photographic properties. The principle involved is apparent. For all the ingredients that are of importance it is necessary only that the original formula contain the *equilibrium amounts desired* and that the replenisher formula be correct. Under these circumstances, there will be no change in coming to equilibrium. These equilibrium

concentrations may be calculated easily since for all cases they are equal to the amounts of the substances formed per minute divided by the liters per minute of replenisher to be supplied to the solution. The elon, hydroquinone, and sulfite concentrations of the original solution are arbitrary, but a correct replenisher must contain the same amounts *plus* the amount per minute to be used up in the machine. The total alkali concentration must be the same in both cases except that since hydroxide is released by air oxidation, and silver halide oxidation releases acid, either acid or hydroxide, respectively, must be added to the replenisher if the rate of production of the one during use of the bath exceeds that of the other. The addition should preferably be in the form of sodium hydroxide or hydrochloric acid so that the alkaline salt equilibrium of the solution is not upset. Silver iodide in infinitesimal amounts may have to be added. Antifoggants present in used developers may call for the addition of small amounts of antifoggants to fresh solutions.

It is important to note in this connection that the alkalinity of the bath *at equilibrium* can not be calculated by the equations given here. It can, however, be held at that of the original mix. When free acid or hydroxide is added to a complex solution such as is used for developers, the change in alkalinity or *p*H of the solution depends more upon the nature and concentration of the compounds present than upon the amount of the acid or alkali added. It is entirely possible to calculate the amount of hydroxide formed by air (from sulfate determinations) and the acid released on development (from bromide analyses) and to correct for these by acid or alkali in the replenisher. Measurements of *p*H will show whether or not *excess* has been added by indicating a *change* in alkalinity, although the measurements must be very precise if they are to be of value. In general, however, *p*H measurements can not be used to calculate the amount it is necessary to add unless careful calibration of the *particular solution* has been made in these terms.

While some assumptions have been made in arriving at the equations above, the only serious discrepancy to be expected is that due to incomplete mixing in the machine. This can be estimated satisfactorily only for a given system. A further assumption has been made; namely, that air and silver oxidation are always present simultaneously. In systems in which it is customary to circulate the solutions for a long time before film is started this difference must be taken into account. For this problem there seems to be no com-

plete solution except a different replenisher formula for each condition.

It is now practical to consider the economic phase of the problem. The factor that determines the concentration of all the products has been shown to be the replenisher rate. If a definite complete formula for the bath is prescribed and can not be altered, this is where the matter stops; there is only one replenisher formula and one replenisher rate possible. Assume for instance, that the formation of bromide is the most important reaction and the original formula which is not to be changed contains 0.5 gram per liter of this substance. Then if 15 grams per minute are formed by the development of the film, the replenisher rate for the system must be 30 liters a minute regardless of its size. The formula of the replenisher is then fixed by the amounts of substances, such as developers, that are *used up*.

The determination of the machine formula that will give the most economical operation is quite another matter. Certain things are readily determined. Since as many liters are thrown away as are supplied, the formula should be as dilute as possible in all its *original* constituents except bromide. Since the permissible *concentration* of reaction products formed determines the replenisher rate, the equilibrium concentration of these should be high. From this point on, the cost of the individual chemicals becomes important and a great many questions of quantity against cost and photographic quality arise. The answers to these questions will vary so much with individual conditions that no direct general solution is possible. A few of the opposing facts may be noted. Alkali is cheaper than developing agent and so should be high in quantity so that developing agent may be reduced. Too high a *p*H value and too little developer gives high sensitivity to bromide and interferes with picture quality. High *p*H also usually increases the *rate* of air oxidation. Sulfite is cheaper than hydroquinone but not enough so to warrant using very large quantities. Larger quantities confer upon the bath only slightly better keeping qualities than do reasonable amounts. Hydroquinone is cheaper than elon but the two are not entirely equivalent photographically, as we have seen. The solution should be as dilute as is permissible. Too great a dilution, however, introduces a large difference between the main bath and the replenisher. This in turn accentuates circulation nonuniformities and makes a bad situation if any of the main body of the solution is lost through leakage. In the absence of other considerations the longer the time of develop-

ment and the higher the temperature the more efficient becomes the utilization of the developer. Limits are obviously set by the size of the machine, by aerial oxidation, and by the physical properties of the emulsion gelatin as well as by photographic standards. A high degree of agitation of the developer at the surface of the film is desirable for uniformity, and considerably increases the efficiency of the bath. A *saving* by this means is not to be expected because there is a tendency toward excessive aeration. Considerable heating of the solution also puts an extra load upon the cooling system.

It is true in most cases that the greatest possibility of effecting economy and at the same time making quality more uniform lies not so much in the use of any of the above devices as in obtaining knowledge of the exact status of the bath at equilibrium. With this knowledge it is possible to calculate the correct minimum amount of replenisher that may be added and the formula of the weakest replenisher that may be used.

Nothing has as yet been said concerning methods by which the concentrations of the components of the bath may be checked. Such routine tests should be considered a matter of necessity. Increase in aeration alone, due to the sudden leaking of a pump or to a similar cause may throw the developer badly off standard. Photographic tests have, to date, been nearly the only ones available. These are usually satisfactory (except for the time element) but leave two important possibilities unmeasured. In the first place, until very recent years, there has been no method for checking gradual changes since there has been no way of knowing whether the film or the developer has changed. The present constancy of motion picture positive film characteristics has practically eliminated this problem. Second, it is entirely possible, and, in fact likely, that if the formula for the replenisher is varied to keep the photographic properties constant, there will be a progressive change in both the photographic quality (as distinct from gamma and speed) and in the composition of the bath. Sudden shifts in the quantity of oxygen absorbed by the system may vary the hydroquinone concentration greatly. A sudden leak in the system, if the latter is of the constant-level automatic replenishing type, will introduce large quantities of replenisher unintentionally.

In order to guard against these contingencies and to make certain that no large changes are taking place unintentionally, some sort of a chemical analysis should be made for all the photographically active

constituents. The following analytical scheme, abridged from the articles of Lehmann and Tausch and the Tausch thesis already referred[1,2,3,4] to represent a workable system. Much simpler and faster methods must be devised before analytical methods can become generally applicable. (The hydroquinone analysis given below is a modification by Lehmann and Tausch of the method of Pinnow.[5])

To determine the concentrations of elon and hydroquinone use is made of two facts: First, since the oxidation products for the most part are the monosulfonates of the compounds, they are not extractable from water solutions by immiscible organic solvents such as ether. Second, while hydroquinone may be extracted quantitatively from water if the solution is acidified, this is not true for elon since it forms acid salts. Elon may be quantitatively extracted only in mildly alkaline solutions (pH approximately 7.6). At this pH hydroquinone is also extracted so that it is necessary to remove the hydroquinone first.

The procedure used by Tausch was as follows: 35.7 cc. of developer solution was acidified with sulfuric acid to the point where a few cc. of hydroxide would again make the solution alkaline (permanent blue coloration of Congo red paper). The released CO_2 and SO_2 were removed by evacuation. A few drops of methylorange solution were added and the whole made up to 50 cc.; 35 cc. of this solution was then extracted with peroxide-free ether for 45 minutes and the ether solution separated. The acid water residue containing the elon was then made alkaline using methyl orange as indicator. A further extraction (20 cc. of ether) for 45 minutes removed the elon quantitatively. After evaporation of the ether the two compounds were then titrated with iodine in water solution containing sodium bicarbonate. From the iodine used up the amounts of the agents were calculated for each case.

To determine the sulfite concentration a modification of well known methods was used. A weakly acidified iodine solution (100 cc.) containing an excess of iodine was placed in a flask and 2 cc. of developer was accurately introduced. After a short time the solution was back-titrated with thiosulfate to the starch iodide end-point.

Alkali was determined by titration with acid. Sulfate was determined by precipitating with barium salt and weighing the precipitate. Soluble bromide was obtained in the same manner after precipitation with silver.

By means of these tests it is possible to gauge accurately the proper rate of replenishment and the proper constitution for the replenisher. In addition, measurement of pH would give a still further check on the state of affairs in the bath. It can not be overemphasized, however, that all these tests taken together do not specify the *photographic* quality of the product. They insure merely that the *strength* of the developer does not change. Sulfide-forming bacteria causing fog, by-products of development giving stain, and loss of quality from other sources must be guarded against by an expert capable of recognizing small changes. The present analysis is satisfactory for first-order control only. As has been pointed out, however, the replenisher calculations hold for any product that is continuously formed in the bath. For this reason accurate determination of one product makes it possible to calculate the others at once.

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DISCUSSION

MR. TOWNSLEY: We have had in our laboratory for the past three years a developing machine using continuous replenishment. By a process of cut and try, we have arrived at a replenishing solution that works very well in practice.

We have been able to control both gamma and print density within very narrow limits without resorting to changes in developing time or replenishment rate for over 18 months. During this time we have processed approximately 25,000 feet of 16-mm. film per week. The only control necessary is to compensate for changes in sensitivity and developing rate of film of different emulsion batches. Very careful check has been kept on the installation as a matter of engineering record, to determine how well stability is being maintained over a period of time, and the results have been very gratifying.

SOUND-STAGES AND THEIR RELATION TO AIR-CONDITIONING*

C. M. WERT and L. L. LEWIS**

Summary.—*The development and growth of the modern motion picture sound-stage has almost paralleled that of sound pictures. Weather, lighting technic, and sound recording brought about requirements not originally considered. Modern sound-stages have increased not only in quality but in size, and must have structural strength to withstand the elements. Sound treatment makes necessary other treatment for satisfactory occupancy. Lighting is the greatest contributor of heat within the stage, is variable as to amount and duration, and must be controlled correctly. Size and number of sets are variable and create individual problems, and both the number and types of persons on a sound stage play their parts in relation to the air-conditioning.*

Construction that retards flow of heat through walls necessitates control of the heat. High-salaried personnel, often in costume, demand comfort while working; less time is lost in make-up retouching and less delay brought about by perspiration dampened costumes.

An air-conditioning system should have the ability to heat, cool, ventilate, and clean. Stages are generally maintained at 75°F and 50 per cent relative humidity, with temperature settings above and below, at the option of the occupants. Floor distribution of air has the advantage of more economical removal of rising heat but the disadvantage of placing set construction and personnel too near source of cooling. Overhead distribution has the advantage of better temperature distribution but is less economical in the removal of rising heat from lights.

Sound treatment of an installation is necessary for continuous operation. If the system does not operate continuously the heat load builds up so that the system can not adequately regain comfortable conditions during non-shooting periods. Treatment is by both isolation and absorption of sound, and can be accurately determined and specified.

The development and growth of modern motion picture sound-stages has almost paralleled the development and growth of sound pictures. The addition of sound to action was not the original reason for enclosing the spaces where motion pictures are made. Weather and the advancement of lighting technic undoubtedly brought about the original need for enclosed stages. The advent of sound repro-

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duction not only increased this necessity, but brought about certain additional refinements and requirements not originally considered.

Size of Stages.—Modern sound-stages have increased not only in quality but in size. A recent sound-stage, completely sound-treated and completely air-conditioned, has been built 316 feet long, 136 feet wide, and 55 feet high. The floor area of this stage is comparable to a football gridiron, and its height to a four-story building. Another recent stage, built primarily to accommodate the tremendous sets used in the production of the modern musical revues, has a floor area somewhat smaller; but the ceiling of one-half of the stage is $66^1/_2$ feet high and of the other half of the stage, $96^1/_2$ feet. This $96^1/_2$ foot height is impressive and for comparison we must visualize an eight-story building.

Construction of Stages.—The construction of the sound-stage involves a great deal more than the simple requirement of enclosing a space. The entire structure must be engineered to meet code requirements for earthquake resistance and wind resistance. The stage must have a floor capable of carrying heavy rolling equipment, large sets, and crowds of people. To eliminate columns the roof is of truss construction, designed not only according to the requirements of roof construction, but also to provide support for scenery, catwalks and the various braces, wires, *etc.*, that seem literally to infest the area above a set. The refinements in the design required for the proper reproduction of sound are themselves an engineering problem of great magnitude. This paper makes no attempt to go into this type of engineering. It is sufficient here to say that the entire stage must be sound-proofed against extraneous noises and sound-treated for the proper reproduction of sound within. These requirements involve the selection of proper materials for the control of sound, both as to transmission and absorption. Also, it becomes necessary to break the structural continuity of walls, floors, and ceilings to minimize the sound-carrying vibrations that originate and progress in the structure.

The floor of the sound-stage, particularly, must not be in rigid connection with the wall structure, but must be insulated separately to obviate ground noises, such as those produced by passing trucks. The result of all these requirements is a structure that may be compared to an enormously overgrown refrigerator box. The stage, like the box, is light-proof, air-tight, sound-proofed, and its construction retards the flow of heat in either direction. In this analogy it can be

seen that the obstructions to the passing of light, air, and heat are all intensified by the requirement of a construction necessary for obstructing the passage of sound.

Stage Lighting.—The lighting of a sound-stage is the greatest individual contributor of heat gain within the enclosed space. The total light load is greatly variable, both as to amount and length of time the load is present. The total light load present depends primarily upon the size of the set upon which shooting is taking place. The length of time that the load is present during any one continuous period, and the frequency of these periods, are influenced by the script, the director, the performers, and the ability of the performers' make-up to withstand the effect of the heat produced by the lights.

In the case of the two large stages previously mentioned, provisions were made for 11,000 amperes on the larger stage and 8000 on the other. This is equivalent to an average of 28 watts for each square-foot of stage area. The concentration of the light is much greater, since the area covered by the lighted set is never as great as the area of the stage.

Electricity for the lighting is delivered to the stages in the form of direct current. On the large lots this electricity is generated by d-c. generators driven by a-c. synchronous motors. These motor-generator sets are designed so that the ripples in the d-c. voltage will not exceed $\pm$ 1 per cent. Due to the intensity of lighting required, a greater variation in voltage would create a change in this intensity sufficient to register on the photographic film.

Due to the heavy intermittent load, which might at times overload the feeder to an individual stage, the motor-generator sets are over-compounded approximately 6 volts to compensate for the drop in voltage due to these overloads. Hard arc lighting requires the use of choke-coils to eliminate the sound or whistle created primarily by commutator ripple and attenuated by the high frequency generated in the arc crater of the lamp. Each arc light also has its individual resistor.

Stage Scenery or Sets.—Obviously there is great variation in the size and number of sets on a sound-stage at any one time. At times the entire stage may be utilized as one large set; at other times, numerous smaller sets may be scattered about the stage. These sets vary both as to size and type, to such an extent that we might say that no two are ever alike.

Basically, the sets are three-sided and topless. They are stages

within a stage, and, as such, affect the acoustic conditions of the whole. Proper treatment for this situation provides a medium in the construction of the set that will pass the sound bodily through the set to the treated walls and ceiling of the stage proper. Such procedure calls for the elimination of all hard-walled sets and the construction of sound sets to meet acoustical requirements upon the same basis as the stage proper. One of the steps toward overcoming reverberation within the confined area of the set itself is the use of dyed muslin stretched on wood frames for all smooth-walled sets.

Sets within the sound stage offer their problems also to the lighting engineer and to the air-conditioning engineer who must deliver cooled air properly to the area embraced by the set.

Occupancy of Stages.—The motion picture company, like the electrical power company, sells to the public something that is intangible. Motion pictures, through the medium of reproduced light and sound depict the emotions and personalities of one group of persons, the actors, to another group within whom is created an emotional reaction. The technical side of motion picture making requires not only a great number of persons, but a great variety of trades and personalities. Press agents have given us some idea as to the personalities, but it is not as well known that there are some 278 different trades and professions in the motion picture industry. At one time or another a great number of these are represented on the sound-stage, but we shall make no attempt to enumerate or classify them.

On the large stages previously mentioned, some 400 persons have been anticipated and provided for, but this number may be exceeded on occasions. A number of the occupants are, of course, actors and actresses in costume and make-up. Human occupancy of the sound-stage brings with it certain additional problems, some of which we must admit can not be solved by the slide rule of the engineer.

Necessity of Air-Conditioning in the Sound-Stage.—All the items covered in the general discussion of sound-stages play a part not only in the design of air-conditioning systems for the stage but also a part in the *necessity* of air-conditioning. Basically, sound-stages are being air-conditioned in one degree or another only because air-conditioning has been proved necessary and the results obtained are of economical value.

Necessity as Result of Construction.—The refrigerator construction of the modern sound-stage, with its capacity for retaining the heat generated within it, is a contributing factor to the necessity of air-

conditioning. The cumulative effects of heat generation must be removed if the quality of the stage's availability for continuous use is to be of the same calibre as the quality of its construction. No expense has been spared to further its ability to keep out light, sound, and weather, and this same expense furthers its ability to keep in generated heat and vitiated air. The insulating value of the sound-stage wall can readily be perceived by considering the construction from outside to inside: 1-inch Gunite plaster, metal lath, waterproofed paper backing, laminated wall panel containing air space, 2-inch acoustical rock wool, and 44-40 count flame-proof muslin protected with hardware cloth or chicken wire.

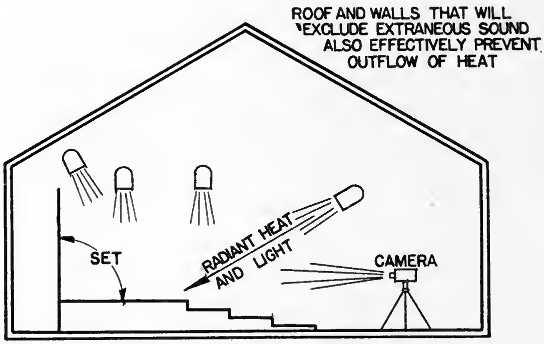
The roof construction is similar in character, although, of course, the Gunite is replaced by roofing. Floor construction consists of 1×6-inch *T* and *G* finish flooring with 2×6-inch sub-flooring, all supported on 2×10-inch floor joists on 12-inch centers. The floor level is 3 to 4 feet above ground level. The sound-stage, with its specially constructed doors closed, can be said to be hermetically sealed.

The construction that we have just described covers one of the most recent sound-stages. All the sound-stages in use may not be typical in construction, but if well-designed, they are typical as regards sound and heat transmission. From this can be seen that the sound-stage is a structure that does not allow the entrance or exit of air, and so retards the flow of heat that practically, if not theoretically, there is no flow of heat through the structure. This quality of the structure brings into being two requirements met by the air-conditioning system: (1) The use of air delivered into the stage for actual transportation of heat out of the stage; (2) The furnishing of new air to meet the ventilation requirements of the occupants.

Necessity as Result of Lighting.—The light load is the most important consideration of the engineer in the design of an air-conditioning system for the sound-stage (Fig. 1). The production of motion pictures is based upon light and its proper application. Light on the sound-stage is artificial light, and emits heat, most of which is in the form of radiant energy that becomes sensible heat as soon as it strikes an absorbing surface. So-called cold light, such as that produced by the firefly, would be very advantageous. It is possible to produce such light by mixing a luminol-caustic soda solution with a hydrogen peroxide-potassium ferricyanide solution, but the cost is more than a million times as great as the light produced with the

modern incandescent lamp.[1] Even though there may be reports to the contrary, air-conditioning is still more economical.

The air-conditioning engineer has been familiar with the problem of lighting and its results for many years. The tendency toward increased lighting in commercial establishments has not caught him unprepared. Published data on the subject are rather meager, due, we believe, to the fact that possibly the "doctor" has recognized and treated the disease successfully without finding it necessary to determine its degree. The number of pills for the patient has been



SOUND STAGE LIGHTING	50 TO 150	WATTS PER SQUARE FOOT
NORMAL OFFICE	FROM 1 TO 4	" " " "
BRILLIANT STORE LIGHTING	10	" " " "

Fig. 1. Diagram of heating element of air-conditioning problem.

determined by his size and the effect of the pill upon previous patients.

Sound-stage lighting is a special problem of great magnitude and importance. The intensity and amount of sound-stage lighting has already been mentioned. Light is produced on the stage by two means: (1) incandescent lamps, and (2) carbon arc lamps, each having its own characteristics. The carbon arc lamps are required for producing intensities beyond the scope of the incandescent lamps. On large sets, where light must be thrown for considerable distance, there will be a preponderant amount of arc lighting, possibly to the extent of three to one. On the average set the ratio of arc to incandescent lighting is closer to unity. All the electrical energy brought into the sound-stage for the production of light eventually is transformed into sensible heat. Fortunately, all the heat is not

released in the area occupied by the people, or what is more commonly called the "breathing zone."

Since the size and cost of an air-conditioning system for the sound-stage is influenced more by the light load than any other single factor, it is imperative that the air-conditioning engineer correctly diagnose the effects of this load in order to produce the guaranteed results within the breathing zone. Providing refrigeration for the entire energy input would be poor economy and, as such, must be guarded against by the engineer. Numerous factors influence the engineer's calculations regarding the effect of lighting upon the size of the air-conditioning system. Some of these factors are:

(*1*) Total average maximum load.
(*2*) Possible intermittent maximum load.
(*3*) Maximum length of time load occurs.
(*4*) Frequency of load occurrence.
(*5*) Possible maximum concentration of load within the stage.
(*6*) Height of the stage.
(*7*) Possible ratio of arc to incandescent lamps.
(*8*) Reflecting characteristics of material lighted.
(*9*) Location of lights.

The factors just given are largely self-explanatory, but two of them, *7* and *8*, warrant additional explanation.

As mentioned before, arc and incandescent lamps have certain individual characteristics. The gas-filled incandescent lamp operated at normal voltage in still air has an energy distribution about as follows:[2]

	Per Cent
Radiation in the visible spectrum	11
Heat as invisible radiation in the infrared region	70
Heat which is conducted away from the filament through the filament supports and leads	3
Heat dissipated by gas convection and conduction	8
Heat radiation by the bulb	8

Hence, from a clear bulb, about 90 per cent of the total energy is in radiant form; *i. e.*, all except that dissipated by the filament supports and leads and by air passing over the bulb. This large amount of radiant energy will not be effective in raising the temperature in the interior of the stage until it has been intercepted by an absorbing surface which, in turn, will dissipate the heat by convection. The

radiant energy will, however, increase the feeling of warmth to the human body by its radiant effect.

On the sound-stage the aforementioned percentage of energy in radiant form is affected, to some extent, by the housing or reflector covering the bulb. The greatest percentage of the energy, however, is still released in the form of radiant energy. All this energy is eventually absorbed by an absorbing surface. The invisible radiation follows the same path as the visible radiation. It is not all absorbed by the first intercepting body but only a certain percentage of it, depending upon the ability or inability of the body to reflect it.

Assuming that it is possible to visualize a single stream of radiant energy striking the floor of a stage set at an angle, a certain portion of this radiant energy being deflected against the wall of a stage set; and in turn visualizing a certain percentage of the energy being deflected upward to the top of the stage, it can be realized that a certain amount of this radiant energy is dissipated on surfaces far above the breathing zone.

Arc lights have an entirely different energy distribution. The 120 volts delivered to an arc light set-up is reduced by resistance to 72 volts across the arc proper. This means that before the arc is produced, 40 per cent of the incoming energy is released in the form of heat from the resistor by convection and conduction. Since a great number of arcs are used to light the set from above, it can be seen easily that arc lighting has a different effect upon air-conditioning design than does incandescent lighting.

Air-conditioning, as regards the light-heat generation, provides the medium for wiping the surfaces exposed to the radiant heat, both visible and invisible; thus increasing the heat removal by convection and conduction. It also provides a medium for removing the heat not transformed into radiant energy.

Necessity Due to Occupancy.—The fact that the sound-stage is occupied is, of course, the basic reason for air-conditioning. It has long been necessary to provide some means of ventilation for spaces occupied by a group of persons in order that vitiated air might be replaced, and of removing heat at a rate depending upon the outside temperature. Certain combinations of various factors resulted in comfortable conditions within the space while other combinations did not.

Air-conditioning was first used in the industrial field for producing and maintaining predetermined temperatures and humidities, regard-

less of outside weather. Applying it to public spaces brought forth the fact that comfort was a marketable product and that the public would patronize more freely spaces that were comfortable.

The next step was comfort for the purpose of obtaining better results from salaried employees. In the sound-stage, where human beings play such an important part in the scheme of things, comfort becomes a necessity rather than something to be hoped for. Heavy costumes and make-up do not go well with incandescent lamps and arcs when the quality of the acting is dependent upon the comfort or discomfort of the actors.

Necessity from Economic Viewpoint.—It is doubtful whether the actual economic dollar value of air-conditioning on sound-stages has ever been calculated. The great number and importance of intangible and variable factors would complicate any such calculation to an enormous extent. Certain factors are present, however, that are self-evident.

In the moving picture business, as in other businesses, time spent is money spent. Satisfactory results can be produced under comfortable conditions more quickly than under uncomfortable conditions. Uncomfortable and often unbearable conditions in unconditioned spaces are fought in many ways; doors are opened between shots for flushing the stage with air; shots are delayed; ice cakes and dry ice are brought upon the stage; shots are made at night. All these expedients lead to loss of time and money. Damage by perspiration to costume and make-up is one of the obvious factors that can easily be seen to have a dollar value. Probably the most conclusive evidence of the economic value of sound-stage air-conditioning is the fact that air-conditioning systems are still being installed by companies that have had previous experience with them.

Application of Air-Conditioning.—Complete air-conditioning of the sound-stage must meet many requirements. The system must be flexible, able at all times to meet the requirement of heat and ventilate properly, clean the air, cool, remove smoke and fog, maintain proper temperature and humidity within the breathing zone, and properly meet various other requirements, each of which presents certain problems and points of interest.

Heating.—Heat production on the sound-stage has been so stressed that the need for heating the stage by the air-conditioning system may not be evident. During the period of set building, before shooting can take place, stage doors are thrown wide open. Some of these

doors are of tremendous size, built for the entrance and exit of large pieces of scenery and can accommodate some smaller sets in their entirety. Some of these doors are 24 feet high and 18 feet wide. California nights are cool, and due to the high ceilings and the resultant stack action of heated air escaping from exhaust openings, the stage tends to fill with cool air, particularly at the lower level. If production is due to start in the morning, heat must be supplied to produce comfortable conditions for the initial occupancy, even though cooling may be required a short time thereafter. Heating, of course, is seldom required during the shooting, except possibly on a stage with a small set during cold weather and on rehearsal stages where no shooting is taking place.

Due to this tendency of the large stages to fill with cool air, it is considered necessary on one large lot to have heat available for nine months of the year.

Ventilation.—Ventilation, or the replacement of vitiated air, is the oldest function of air-conditioning. Under the artificial conditions of indoor life, air undergoes certain physical and chemical changes that are brought about by the occupants. The oxygen content is reduced somewhat, and the carbon dioxide slightly increased by the respiratory process. Organic matter, which is usually perceived as odors, comes from the nose, mouth, skin, and clothing.

The temperature of the air is increased by the metabolic processes and the humidity raised by the moisture emitted from the skin and lungs. Contrary to old theory, the usual changes in oxygen and carbon dioxide are of physiological concern, because they are too small even under the worst conditions. Little is known of the identity and physiological effect of the organic matter given off in the process of respiration. The only certain fact is that expired and transpired air is odorous and offensive, and is capable of producing loss of appetite and a disinclination for physical activity. These reasons, whether esthetic or physiological, call for the introduction of a certain minimum amount of clean, outdoor air to dilute the odoriferous matter to a concentration that is not objectionable.

Ventilation of the sound-stage always exceeds, by many times, the actual requirements for comfort of the occupants. This excess outside air, over and above that required by the occupants, is brought into the sound-stage for the sole purpose of removing the concentrated heat from the upper levels. After it has performed this function it is exhausted and discharged again to the outside atmosphere.

Air-conditioning systems for sound-stages are often designed on the consideration that the minimum amount of outside air will be 50 per cent of the total fan capacity, or the ability to deliver air to the stage. On the large stages designed to hold 400 persons, this minimum quantity of outside air is sufficient for the ventilation requirements of 7500 occupants. For conservation of refrigeration during favorable outside weather conditions and also for the quick purging of smoke and artificial fog, the sound-stage air-conditioning system is always designed for the ability to handle 100 per cent of its capacity from the outside.

Air Cleaning.—Air cleaning, or filtering air, requires little explanation to prove its importance in air-conditioning. The atmosphere in all localities contains dirt and dust to some degree. The accumulation of these particles, even though minute, will eventually interfere with the economical operation of an air-conditioning system. The beneficial effects of clean air as regards health and comfort are very well known. As regards the sound-stage in particular, dust floating in air can not be tolerated since the motion picture camera easily records it.

Cooling.—The cooling function of an air-conditioning system is the function most publicized, and as a result, to the public, the terms "air-conditioning" and "cooling" are synonymous. To the air-conditioning engineer cooling also means dehumidification, or the removal of moisture by condensation; since generally the two functions, removing heat and removing moisture, are necessary and are performed by the same equipment at the same time.

As regards the sound-stage, cooling and dehumidification are the functions of air-conditioning systems that remove, from a predetermined volume of air, a predetermined amount of heat and moisture; so that the delivery of this predetermined volume of air to the sound-stage and the absorption by the air of a certain amount of generated heat and moisture, will result in a temperature and humidity comfortable to the occupants.

The heat and moisture present on the sound-stage determine the heat and moisture content required of the air delivered to the sound-stage. When the temperature and humidity of the outside atmosphere are higher than required for the delivered air, refrigeration must be used to produce the results desired. The delivered air is cooled either by contact with a fine spray of cold water or by contact with coiled metal surfaces containing the refrigerating medium,

either gas or liquid. Refrigeration is accomplished by either reciprocating or centrifugal type refrigeration machines.

The intermittent and variable heat load present on sound-stages makes the storage type of refrigeration particularly applicable. The maximum heat load on the sound-stage is present during the periods of shooting, which are variable as to both time and number. Sufficient instantaneous capacity furnished by a refrigeration machine alone would require a machine of great capacity (Fig. 2).

A storage type of system combines a large tank or reservoir of cold water, and the refrigeration machine. With this combination it is possible to use a smaller refrigeration machine operating con-

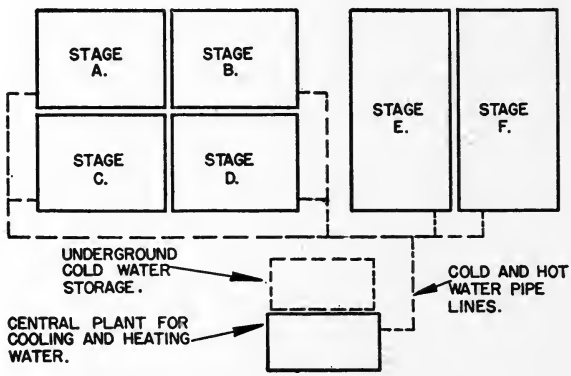


FIG. 2. Water circulating system.

tinuously at maximum efficiency. During the period when no shooting is taking place the excess capacity of the machine is conserved in lowering the temperature of the reservoir of water. During the period of shooting, when the heat load within the stage is greater than the capacity of the machine, additional cooling is furnished by the tank in sufficient quantity to meet the requirements of the heating load. A large refrigeration machine meeting the requirements of intermittent and variable loads does not compare favorably, economically, with a smaller machine running continuously at maximum efficiency. The requirements and total cooling by both set-ups are, of course, identical.

Exhaust.—The construction features that render a sound-stage air-tight also lead to the necessity of exhausting air from it. Air from the outside is necessary, and unless air be removed from the

inside, the amount that can be introduced will be limited by the pressure-producing ability of the supply fan. When the pressure within the stage reaches the limit of the fan's capacity, no more air from the outside can enter. The expedient of providing openings for relieving the inside pressure is not satisfactory, since this requires an internal pressure to force out the air, and the pressure required would be increased by the necessity of sound-treating the exhaust openings. Pressure inside the sound-stage is objectionable due to its effect upon the operation of the doors. An unbalanced pressure on the two sides of the large doors will prevent opening them, and inside pressure interferes with the proper closing of the smaller pedestrian doors.

Mechanical exhaust permits maintaining the pressure inside the stage equal to the pressure outside the stage, by overcoming the resistance of the exhaust openings. It permits also the use of smaller exhaust openings, which can be more satisfactorily and economically treated against sound transmission. Proper location of the exhaust openings at the highest level enables the exhaust air to pick up the greatest amount of heat and arc light smoke and carry it to the outside.

The capacity of the exhaust system is variable, to agree with the ability of the supply system to deliver variable quantities of outside air to the stage. For very fast purging of the stage after heavy smoke or fog scenes, full capacity of the exhaust system is used, with all doors opened and the supply system not in operation.

Air Distribution.—Air distribution on the sound-stage is quite important in that the complete success of the system depends largely upon the results obtained by the distribution. It is necessary to handle large volumes of air to compensate for the heat concentration without creating discomfort to the occupants.

The air-distribution system must be flexible so that extra air may be concentrated at any particular section of the stage if desired (Fig. 3). Quite often a distribution that is satisfactory for a certain number of sets may require alteration for another group of sets. The temperature and humidity are important only in the breathing zone, and the distribution system should not be arranged in any manner that would have a tendency to interfere more than necessary with the natural tendency of heat to rise and stratify.

The most economical air-conditioning system, of course, would be one that conditions the floor area to a height of only seven or eight

feet. Practically, this is impossible, but the air-conditioning engineer approaches this ideal as nearly as possible in design, limited only by other requirements. Some of the original sound-stages were conditioned by introducing conditioned air along the side walls and near the floor level. The air was delivered at a low velocity, out across the floor, where it picked up the liberated heat in the breathing zone, rose to the top of the stage, and was pulled away by an exhaust fan. This form of distribution really delivered the air directly to the

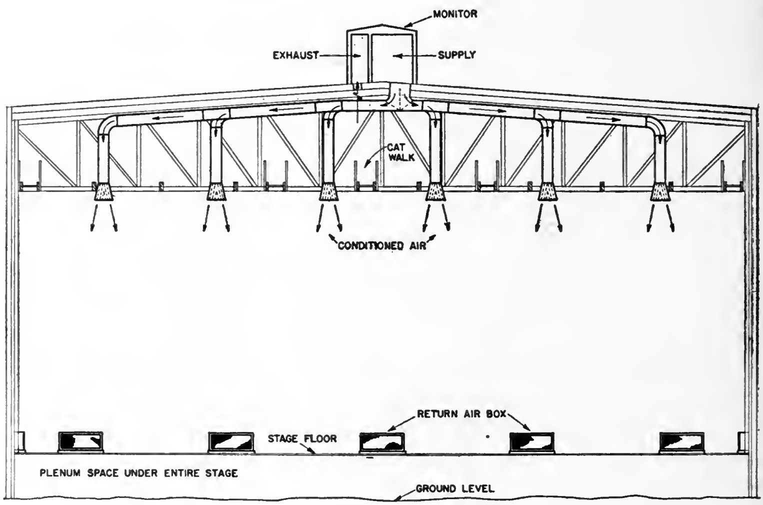


FIG. 3. End section of sound-stage.

breathing zone, and very little cooling effect was wasted at the higher, unoccupied level.

Difficulties began to arise when it was found impossible to prevent the building of sets and drops directly in front of the supply outlets; which, of course, prevented a part of the air from reaching the occupied spaces of the stage. Also, occupants having duties other than acting often had to be located near the supply outlets; which, of course, led to complaints, and rightfully so, since the temperature of the air at the delivery points was considerably below the resulting room temperature after the air had absorbed its heat. These objections were intensified by the tendency of the companies to do more and more of their shooting inside the stages, with a consequent increase in the size of the sets and bringing them closer and

closer to the walls of the stage. It was then the problem of the air-conditioning engineer to overcome these objections and still retain, in a measure, the original intention of applying the conditioning primarily to the occupied space or breathing zone.

Increased size and variable location of the sets made it inevitable that the air must be delivered from above the set. This led to a design that would enable delivery of conditioned air downward against a blanket of heated air rising upward. The process of adding cold water to a tub of water too hot for comfort is well known—the cold water sinks to the bottom of the tub and forms a cool layer, displacing the hot water, which is forced upward. In order to get an even temperature it is necessary to agitate and mix the cold and hot water. Somewhat the same principle is applied to the downward distribution of air. The cool, or conditioned, air is not only heavier than the warm air, but it is started in a downward direction by a low velocity produced by the supply fan. Cool air actually displaces the warmer air and the mixing is accomplished by friction or contact along the perimeter of the cool air stream. Supply outlets are designed to keep the cool air stream as confined as possible for as great a distance downward as possible, but also with the purpose of reaching the full area of coverage at the top of the breathing zone. This distribution can be visualized by picturing a great number of slender pyramids hanging by their apexes from the sound-stage roof, with their bases touching on all four sides at a level seven feet above the floor. All the space above the bases and between the pyramids would represent the space through which heated air could rise. This final blanket of air at the top of the breathing zone must reach there at sufficiently low velocity as not to produce objectionable drafts. Reverting to the bath-tub analogy, it must be noted that agitation, or mixing, has been guarded against as much as possible.

The exhaust openings of the sound-stage are located at the roof level, and the bottoms of the supply outlets are located at the level of the bottom of the truss structure. The air-conditioned sound-stage, when in operation, has at the bottom a layer of air in the proper conditions; and at the top, air that has been heated. The air at the top, during operation, is generally warmer than outdoor air, and also contains smoke from the arc lamps. Being worthless, it is discharged to the outside atmosphere.

The conditioned air at the bottom of the stage is often more desirable than the outdoor air, and is drawn off at the floor level and returned

to the conditioning system where it is mixed with an additional supply of outside air. To maintain a balance of pressure inside and outside, the exhaust system removes heated air from the top of the stage in the exact quantity as outside air is added to the system. The quantities of air supplied to the stage, taken from the outside, and exhausted from the stage are all manually adjustable from inside the stage.

Inside Atmospheric Conditions.—Although other features might possibly influence the buyer's satisfaction, the resulting inside atmospheric condition is the main yardstick for determining the success of an air-conditioning installation. Systems are designed for the express purpose of producing certain atmospheric results within the sound-stage, and it is normally a requirement of the air-conditioning contractor to guarantee the production of those results.

For economic reasons various limitations are placed upon design of air-conditioning systems. Extremes of short duration (in occupancy, lighting load, and outside weather) are not considered; especially since several extremes may not simultaneously occur. Guaranteed summer cooling requirements in southern California are a temperature not exceeding 75°F and a humidity not exceeding 50%; with outside conditions not exceeding 90°F dry-bulb temperature and 70°F wet-bulb temperature.

Heating design is generally based upon maintaining a temperature of 70°F when the outside temperature is not lower than 30°F. Due to the large volume of the sound-stages, a more important requirement is sufficient heating capacity to bring up the temperature within the stage to the desired point within a stated time, generally ninety minutes.

With present-day knowledge the air-conditioning engineer can predetermine the most economical design of a system having the capacity to produce guaranteed results.

Present Air-Conditioned Stages.—The history of air-conditioning of the sound-stage is almost covered by the past ten years. The present tendency toward doing more of the work inside the stages, aided considerably by the advances made in using process backgrounds will undoubtedly increase the application of air-conditioning to sound-stages. At the present time three major companies, namely, Twentieth Century-Fox, Paramount, and Metro-Goldwyn-Mayer have a total of thirty-five air-conditioned sound-stages.

Application of Sound Treatment to Air-Conditioning.—The advent

of sound reproduction into the radio and motion picture industry caused the air-conditioning engineer to take up the study of sound. It not only became necessary to provide air-conditioning for broadcasting studios and sound-stages without objectionable sound, but the advance of sound pictures proved that many existing theater installations required treatment and adjustment. The following discussion covers the general application of sound treatment of the

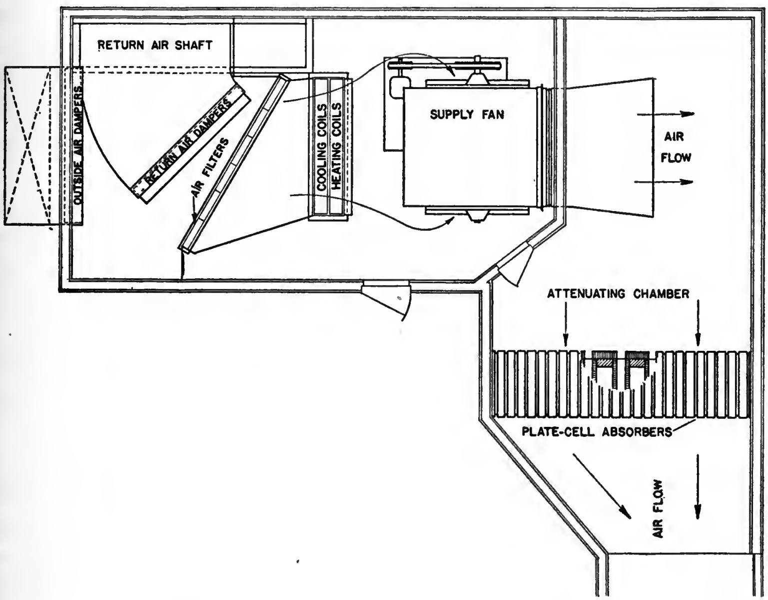


FIG. 4. Detail of supply apparatus (*plan*).

air-conditioning system for the motion picture sound-stage (Figs. 4 and 5).

Necessary for Sound Treatment.—At first thought there seems to be no reason proving the necessity of sound treatment for sound-stage air-conditioning systems, since the necessity seems obvious. At the present time there are several degrees in the quality of sound treatment, both on air-conditioned stages and on stages not conditioned. In some cases doubtless the requirements became more stringent, and left the treatment inadequate. Regardless of the reasons why, stages with and without complete air-conditioning can be placed in two classes; those on which shooting can take place with the system

running, and those on which the system must be shut down. The stage upon which the equipment must be shut down of course receives no ventilation or cooling during the period of greatest heat generation. This form of operation leads to building up the heat so that it may eventually get beyond the capacity of the air-conditioning equipment to handle it, and on the unconditioned stage leads much faster to an unbearable condition.

Proper sound treatment, correctly engineered, will enable full-time operation of the air-conditioning system and not interfere with the reproduction of sound. The modern sound-stage is a quality structure, designed and built for a specific purpose, and it is only fit

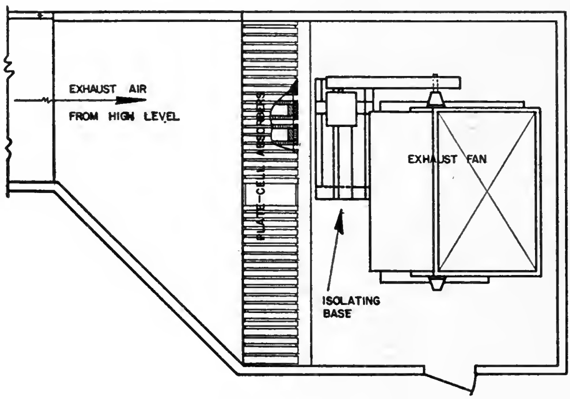


FIG. 5. Detail of exhaust apparatus (*plan*).

and proper that the air-conditioning system for such a structure should be commensurate in quality and ability to perform its duty at all times.

Method of Sound Treatment.—The objectionable noises that might enter the sound-stage due to the air-conditioning installation may be grouped into two classes:

(1) Noise transmitted through the building construction, such as from machine mountings and vibrations, and from equipment through room walls and floor surfaces.

(2) Noise transmitted through air-carrying ducts, such as from fans, from outside through duct walls into the air stream, and noise generated by the flow of air.

Noise that might be transmitted through the building structure can be taken care of very rapidly. All moving equipment is placed upon properly designed isolation supports so that objectionable vibrations may be absorbed. Flexible connections are used between moving and stationary pieces of equipment. The equipment rooms of sound-stages are not only designed to prevent passage of noise from their structure, but are located outside the stage.

Noise transmitted through the air-carrying ducts is not so readily overcome. It is impossible to select air-handling equipment for air-conditioning that will operate without producing some noise that will be carried by the air stream. However, the noise is kept as low as possible by properly selecting the equipment, not only as regards the amount of noise produced, but as regards the frequency of the sound. All duct work outside the sound-stage is insulated to an extent equivalent to the stage wall's ability to exclude sound. Noises generated by the flow of air are prevented by properly designing the duct system and individually treating the parts of the system having a tendency to generate noises due to contact with moving air.

After all the prevention expedients are taken care of by proper design, it is possible to calculate the natural absorption of the system since all air-conditioning systems using ducts for carrying the air have a certain capacity to lower the generated noise level. In sound-stage applications the construction of the stage and distance of the air openings from the point of reproduction play a part in reducing the sound level. The allowable sound level is specified and determined by the stage reproduction requirements and design. The difference in sound level between the allowable level and the calculated level of the system determines the additional sound treatment that must be applied to the system. Many materials are now rated by the manufacturers with sound-absorbing coefficients, and there are several methods of application, generally determined by the arrangement of the parts making up the installation.

One part of the treatment generally used in sound-stage conditioning systems is the concentration of the absorbing material at one point, in cells or passes through which the air must flow. Plenum effects, wherein fans are discharged into large acoustically-lined chambers, the discharge velocity being impacted against the walls of the chamber, have also proved very effective.

Space does not permit going into the details and theory of sound treatment. Suffice it to state that the required treatment can be

determined as effectively as other air-conditioning requirements of the sound-stage, to the point of making and delivering predetermined sound level guarantees.

Guarantees.—The following guarantee, made on a recent sound-stage air-conditioning installation, points out not only the requirements of the guarantee, but the ability of the contractor to meet these requirements:

"It is agreed that the increase in noise level in any of the six conditioned stages resulting from the normal operation of the completed air-conditioning system shall not exceed a value equivalent to an energy level of 29 decibels above an arbitrary established zero sound level of 10^{-16} watt per square centimeter over a frequency range of 30 to 300 cycles, and shall not exceed a value equivalent to an energy level of 19 decibels over a frequency range of 300 to 10,000 cycles. In all cases the noise level shall be measured at a representative microphone location and at a level of five to eight feet above the floor, but in no case shall the measurement be taken closer than 5 feet to any wall. The equivalent loudness shall be determined from 30 to 10,000 cycles either by a weighted electrical network or by a hand frequency analyzer."

Acknowledgment.—The authors wish to acknowledge their appreciation of information given to them by J. M. Tobin and C. P. Hubert of the Metro-Goldwyn-Mayer Corp., and E. L. Ellingwood, Consulting Engineer, Los Angeles, Calif.

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NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

PROBLEMS IN THE USE OF ULTRA-SPEED NEGATIVE FILM*

P. H. ARNOLD**

New photographic problems have arisen from the introduction of motion picture negative films having a greater increase of speed over the prevailing types than the supersensitive panchromatic films had at the time of their introduction.[1] Some of the problems confronting motion picture cameramen and laboratory technicians can be considered in the light of solutions that have been evolved by theory and practice.

In general, Ultra-Speed panchromatic film, compared to Superpan negative film, is much faster; slightly flatter in gradation; similar in color-sensitivity, with slightly greater response to red light; and possessed of a somewhat coarser grain. Of these characteristic differences, the speed relationship has the greatest magnitude.

The Problem of Correct Exposure.—A wide variety of tests made under a number of conditions of practical photography[2] have shown that Ultra-Speed panchromatic film is correctly exposed when given two lens stops less exposure than Superpan negative film. Since the principal application of the film tends toward those conditions of photography or to cinematographic subjects that have been considered difficult to photograph or impossible to record because of insufficient illumination (Fig. 1) the problem of correct exposure can not always be solved by reference to correct exposure technic for supersensitive panchromatic negative films. Actinometers, or exposure meters, are of little assistance under these dim light conditions since the camera position is usually remote from the subject, which, in turn, is often inaccessible for average brightness measurements. Moreover, the photographic subjects made practicable by the Ultra-Speed panchromatic film usually have too low a brightness level to activate photoelectric exposure meters in common use. Fortunately the sensitivity characteristics of the new film are sufficient to produce successful pictures under typical indoor illumination, with normal shutter angles and at camera speeds of 24 frames a second, using

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* Received May 4, 1938.

** Agfa Ansco Corp., Binghamton, N. Y.

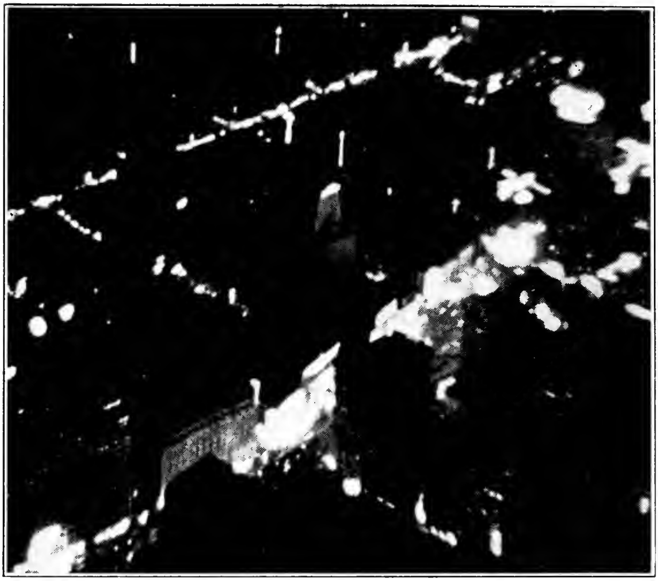

Fig. 1. Airplane view of New York City: Taken about 7:30 p.m., Nov., 1937, on Ultra-Speed panchromatic negative film in Akeley silent camera with 2-inch $f/1.4$ lens, by *News of the Day*.

Fig. 2. Counting ballots in New York City Armory: Photographed by *Pathe News* on Ultra-Speed panchromatic film without additional illumination.

lenses having relative apertures of $f/2.3$ and, in some cases, $f/3.5$ (Fig. 2). The speed of the film is not appreciably affected by age. No allowances need be made

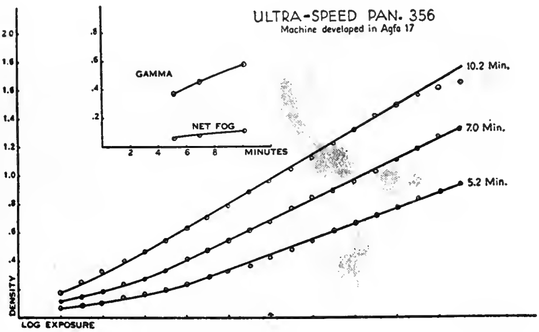

FIG. 3. Characteristic curves obtained by exposing Ultra-Speed panchromatic film in a Type II*b* sensitometer and developing on a motion picture negative developing machine.

in exposing old film since the Ultra-Speed film has proved to have exceptional stability with respect to speed and gradation, as well as resistance to fog and deterioration during a period of eleven months.

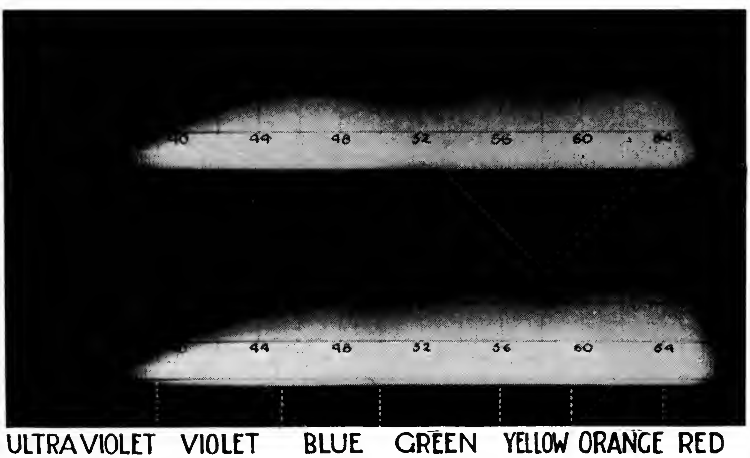

FIG. 4. Wedge spectrograms (tungsten) on Superpan negative and Ultra-Speed panchromatic film.

In newsreel cameras that record sound on the same film with the picture image, a reduction of lamp current of approximately 15 per cent has been found adequate

to compensate for the speed difference between Ultra-Speed panchromatic film and supersensitive panchromatic negative films. The introduction of a Wratten No. *47* (*C-5* tricolor blue) filter into the optical system of the recorder accomplishes the same purpose without requiring alteration of the lamp current.

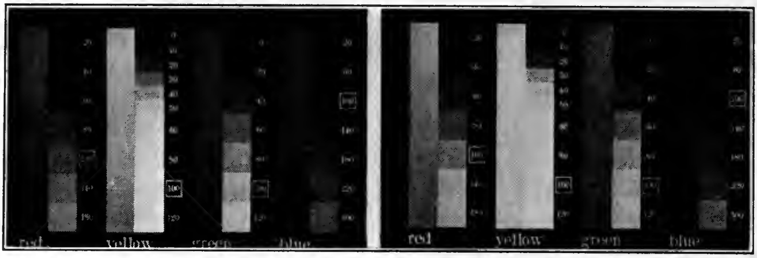

FIG. 5. Photographs of color charts by light of daylight quality on Superpan negative (*left*) and Ultra-Speed panchromatic film (*right*).

When exposed on typical sensitometers available in commercial motion picture laboratories, Ultra-Speed panchromatic film records density on all the steps (Fig. 3) because, when these instruments were designed, films having the sensitivity of Ultra-Speed panchromatic film possibly were not contemplated; whence

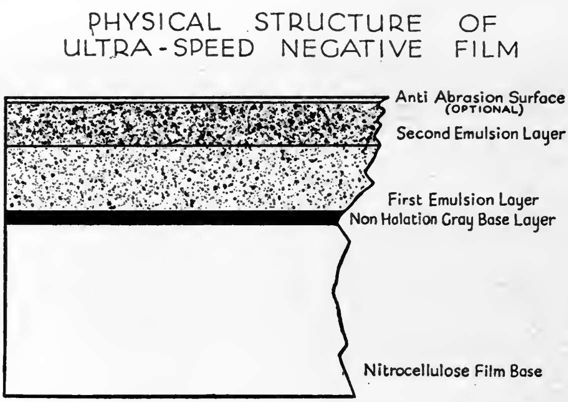

FIG. 6. Structure of Agfa motion picture negative film, showing location of gray anti-halo layer.

the sensitometers have been calibrated to suit the speed characteristics of the supersensitive panchromatic emulsions. In order to study the threshold or shadow density characteristics of the Ultra-Speed film, the addition of a 25 per cent neutral density filter has been found advisable, since it produces sensitometric strips having the required range of density without altering the characteristics of the lamp or disturbing the calibration of the sensitometer.

Other Problems of Exposure.—The speed advantage of two diaphragm stops, of Ultra-Speed panchromatic over Superpan negative film, is fairly constant under various daylight and artificial lighting conditions,[2] indicating close similarity in the color-sensitivity characteristics of the two films. Wedge spectrograms, however, show that the Ultra-Speed film has a slightly greater range of sensitivity to red light than the previous film (Fig. 4) and photographs of the color chart (Fig. 5) show that Ultra-Speed panchromatic film has about 20 per cent greater response to red-colored objects than the old Superpan negative film. The photographic problem introduced by these color-sensitivity dissimilarities is not great and in most cases can be neglected with confidence. No special character make-up has been found necessary with the Ultra-Speed film even under 100 per cent tungsten illumination.

Problems of Printing and Development.—In timing negatives made on Ultra-Speed and Superpan negative film, no allowances need be made for differences in the gray-base color, since they both have the same type of neutral gray anti-halation layer (Fig. 6) on the base underneath the emulsion. When combined for printing with other negatives having lavender, pink, or orange-tinted gray bases of similar optical density, the Ultra-Speed panchromatic film may appear to be only three times instead of four times as fast, due to selective absorption of the printing light[2] by the tinted gray bases. From three to five printer points may be required to compensate for the filter effect of tinted gray bases that depart markedly from a neutral gray.

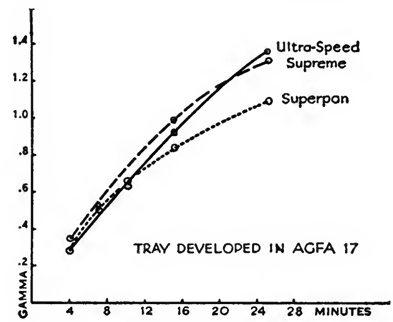

FIG. 7. Gamma *vs.* developing time relationship of Ultra-Speed panchromatic Supreme, and Superpan negative films.

When developed for a gamma of 0.65 or lower, Ultra-Speed panchromatic film has a flatter gradation than Superpan negative film given the same treatment (Fig. 7). When developed for a gamma of 0.7 or higher, the Ultra-Speed film becomes progressively steeper in gradation than Superpan negative film given the same treatment. Considering the contrast relationship of the two films in the range of negative gamma normally employed in professional motion picture work, together with the photographic characteristics of the subjects that usually will be photographed on Ultra-Speed panchromatic film, best screen results appear to follow the practice of developing Ultra-Speed panchromatic film about 20 per cent longer than Superpan negative film.

In professional motion picture work, Ultra-Speed panchromatic film will, of necessity, be developed under normal negative processing conditions in prevailing types of developer, with the correction in time of development noted above. Tests with a number of developer solutions of interest to the photographer who uses motion picture negative film in miniature cameras for still photography have shown that Ultra-Speed panchromatic film behaves at least as well as Superpan negative in these solutions. For example, the rate of exhaustion of developer

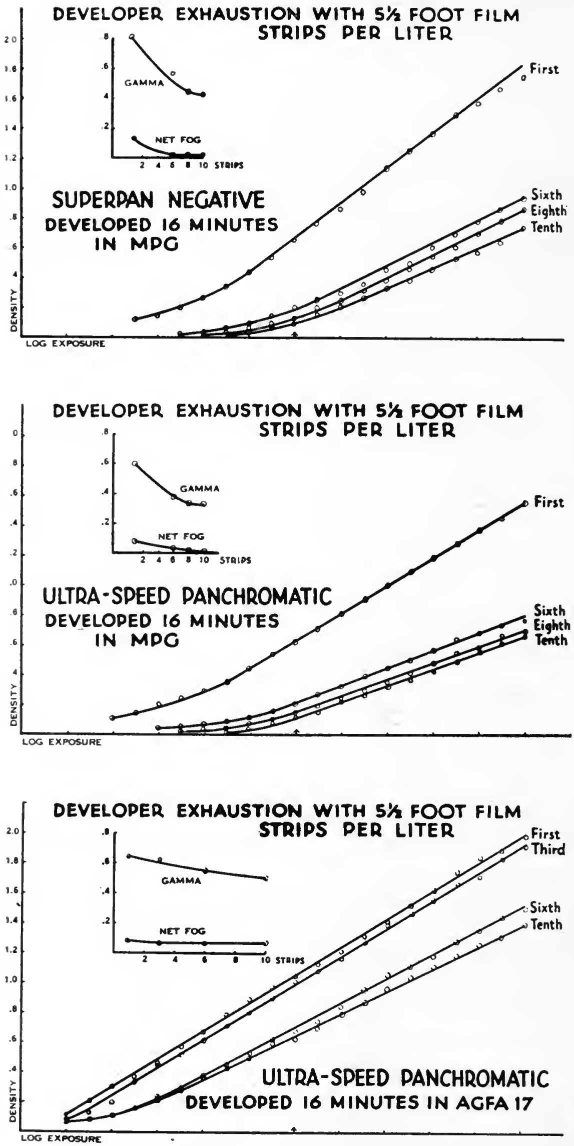

Fig. 8. Rate of exhaustion of developer by successive units of Ultra-Speed and Superpan negative films. The exhaustion rates of two different developers are also shown.

per unit of film developed was the same for Ultra-Speed panchromatic film as it was for Superpan negative (Fig. 8). Experience gained in processing typical motion picture negative films can be freely applied to the development of Ultra-Speed panchromatic film.

No advantage is gained with the Ultra-Speed film by the use of fine-grain developers of the sort that reduce the speed of the film. Greater efficiency and

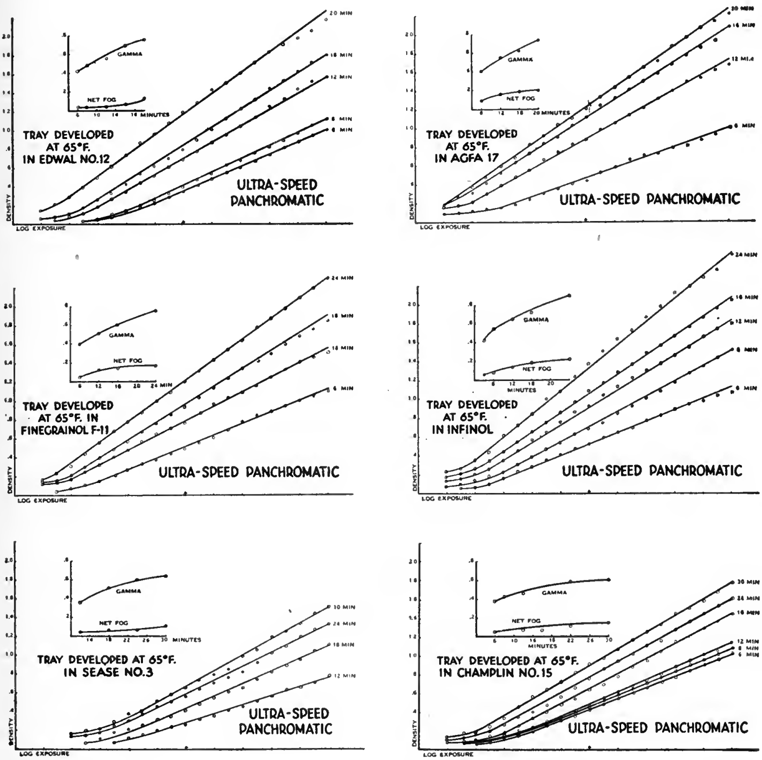

FIG. 9. Characteristic curves of Ultra-Speed panchromatic film developed in various solutions used for miniature camera photography on motion picture negative film.

better photographic quality is assured by employing a film such as *Supreme* negative,[3] which is already slower than Ultra-Speed panchromatic film (but twice as fast as Superpan negative) and capable of exceptionally fine-grain results in motion picture negative developers of the types that bring out the full speed of the film.

The sensitometric characteristics of Ultra-Speed panchromatic film developed in a number of developer solutions used with miniature camera exposures on motion picture negative film are shown in Fig. 9, and the time-gamma informa-

tion obtained in these studies is compared in Table I. These data, in some cases, differ from recommendations already given for use with some of the solutions in developing Ultra-Speed panchromatic film. The effect of the several developers upon the speed of the film parallels the results obtained with other negative films: the highest effective film speeds were obtained with developers of the motion picture borax type, while the lowest speeds were obtained with the

TABLE I

Gamma Obtained in Various Solutions by Tray Development of Ultra-Speed Panchromatic Film at 65°F

Developing time in minutes	8	12	16	20	24
Agfa *17*	0.36	0.56	0.65	0.70	
Sease No. *3*		0.33			0.50
Infinol	0.40	0.52	0.62	0.67	0.82
Finegrainol *F-11*	0.41	0.51	0.63		0.72
M. P. G.		0.55	0.64		0.76
Edwal *12*	0.48	0.58	0.64	0.74	
Champlin *15*	0.43	0.44	0.55		0.57

paraphenylenediamine-glycin developers, and intermediate speeds resulted from the latter type of developer solution fortified by additions of metol. A comparison of the relative speed attained with the Ultra-Speed film in the different developers is shown in Table II, the relationships being expressed in terms of stops and half-stops on the lens diaphragm that would produce similar negatives under the different conditions of development.

TABLE II

Approximate Diaphragm Stop Required to Produce Negatives of Same Density on Ultra-Speed Film Using Different Developer Solutions

	Diaphragm Stop
Agfa *17*	*f*/16
Sease No. *3*	11
Infinol	16
Finegrainol *F-11*	16
M. P. G.	8
Edwal *12*	11
Champlin *15*	12.5

Safelight Requirements.—So sensitive is Ultra-Speed panchromatic film to light of all colors that it must be handled and developed in total darkness. Green safelight filters that have proved practicable for use with supersensitive panchromatic film will fog the Ultra-Speed film. Very brief inspection of the wet film is permissible during development, using a panchromatic green safelight such as the Agfa No. *108* with one-half the illumination that would be safe for supersensitive panchromatic film.

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HUSE, E., AND CHAMBERS, G. A.: "Eastman Super X Panchromatic Negative Motion Picture Film," *Amer. Cinemat.* **XVI** (May, 1935), No. 5, p. 186.

[2] ARNOLD, P. H.: "Sensitivity Tests with an Ultra-Speed Negative Film," *J. Soc. Mot. Pict. Eng.*, **XXX** (May, 1938), No. 5, p. 541.

[3] STULL, W.: *Amer. Cinemat.*, **XIX** (Jan., 1938), No. 1, p. 10.

PERMANENT-MAGNET FOUR-RIBBON LIGHT-VALVE FOR PORTABLE PUSH-PULL RECORDING*

E. C. MANDERFELD**

The light-valve described in this paper has been designed specifically as a part of recently developed portable recording equipment when used for push-pull recording. As space is limited in portable equipment, the light-valve was designed to obtain the smallest practical mechanical structure and yet allow the adjustment and maintenance advantages of the standard four-ribbon valve used with fixed channel recording machines.

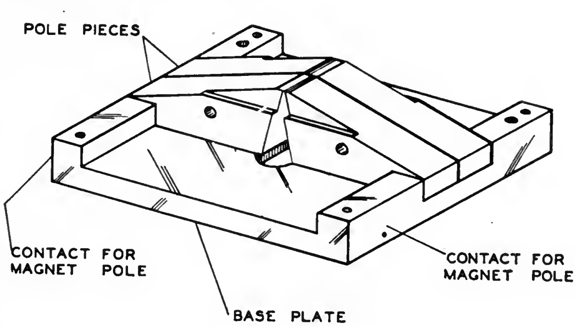

FIG. 1. Showing arrangement of pole-pieces and base plate.

Referring to Fig. 1, it will be noted that four of the pole-pieces (there are four on the bottom and four on the top) are mounted in a shallow slot in a soft steel base-plate. The pole-pieces are accurately machined pieces of "Permendur,"

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 20, 1938.

** Electrical Research Products, Inc., Hollywood, Calif.

a material having the characteristic of high flux transmitting capacity. The pole-pieces are located in the proper position on the base-plate, as well as the cap-plate, by means of an assembly jig and are locked in place by small screws. Pass-

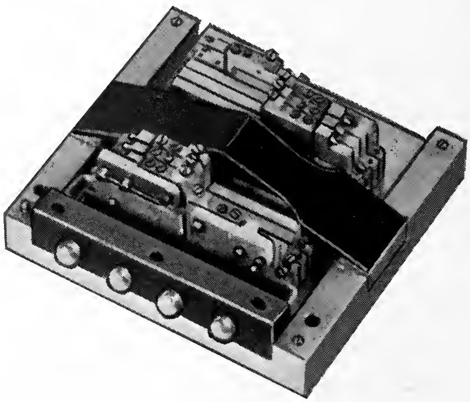


FIG. 2. Top view of pole-piece assembly.

ing through the sides of the pole-pieces on the base-plate are holes so located in each piece as to form a continuous through hole for each pair of poles when properly assembled on the base-plate. This hole is a clearance hole for a through screw that holds the ribbon clamping and adjusting bar assembly to the sides of the pole-piece structure. The arrangement is shown in Fig. 2. The clamping

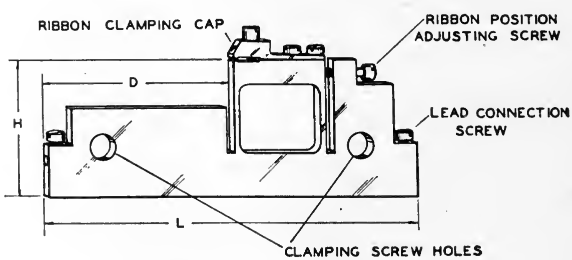


FIG. 3. Clamping bar.

bars, one of which is shown in Fig. 3, are made of steel hardened after machining. The overall length L of all eight bars is identical, but the height H and the distance D vary. The variation in height H is to allow the ribbons, when clamped, to lie in different planes so that they can pass without clashing. In addition, the two end bars on each side are provided with means to move the clamping edge

along the ribbon line for ribbon-tension adjustment. The ribbon-clamping caps are made of steel and are the same for all the clamping bars.

The holes for the screws holding the clamping bars against the sides of the

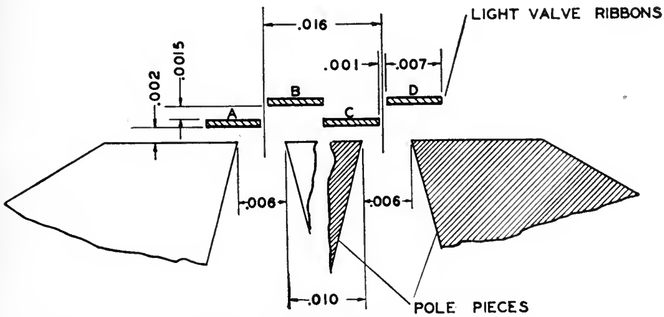


FIG. 4. Cross-sectional view showing positioning of ribbons.

pole-pieces are of sufficient size to allow electrical insulation between the clamp bars and the clamping screws. The individual clamping bars are insulated from each other by means of thin bakelite washers 0.012 inch thick. The electrical connections are made at either end of the clamping bars by means of a stiff con-

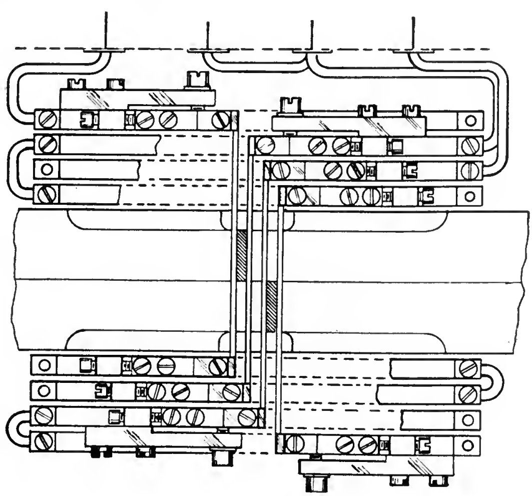
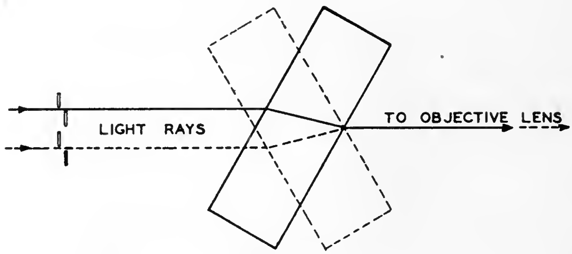


FIG. 5. Arrangement of ribbons over pole-pieces.

necting wire set in a small hole and locked in place by a set screw. To locate the clamping bars properly on each side of the pole-piece structure, a jig is used during assembly which aids in obtaining the proper height H and the proper distance D of all the bars

The cross-section position of the ribbons when placed between the clamping points is shown schematically in Fig. 4. It will be noted that ribbons *A* and *C* are placed on a horizontal plane 0.002 inch above the top faces of the pole-pieces, whereas *B* and *D* are placed slightly higher to give about 0.0015 inch of clearance between the two sets of ribbons. Ribbons *A* and *B* act as one pair and *C* and *D* as the other pair, but being offset in height, they will not mechanically clash if the



6. Refractor prisms.

ribbon amplitude should momentarily exceed the prescribed amount. The spacing for either pair of ribbons can be set for rather wide limits, but normally it is 0.001 inch. The center-lines of the two pairs of ribbons are spaced 0.016 inch apart.

Fig. 5 schematically shows how the individual ribbons are arranged over the pole-pieces. It shows how the two end-clamps are arranged to allow tuning adjustment for any ribbon, as well as how the electrical connections are made. It

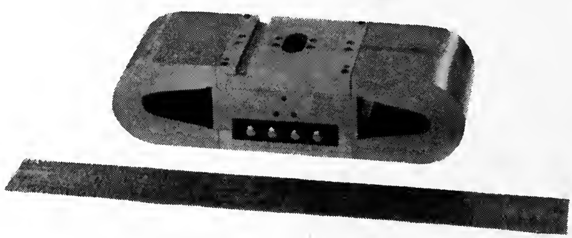


FIG 7. Light-valve and double-magnet assembly.

will be noted that although all the ribbons are of the same length, the dimensions are such that the longitudinal center of each ribbon coincides very closely with the center of its associated pole-piece opening, thereby minimizing bowing effect.

Inasmuch as the center-lines of the two ribbon pairs are located 0.016 of an inch apart, means must be provided to align these center-lines at the film. This is done by small refractor plates mounted in the cap pole-pieces, the principle of which is shown schematically in Fig. 6. One refractor plate and one pair of ribbons are shown solid in this sketch, whereas the other set is shown dotted. The

rays from the condenser lens pass through the light-valve ribbon opening and strike the glass refractor plates at an angle. The rays are then refracted toward the normal, depending upon the angle of the plate and its index of refraction, and emerge from the other side of the refractor plate at the same angle at which they entered, but displaced in the vertical plane, provided the sides of the refractor plates are optically parallel to each other. Thus the objective lens sees the two halves of the light-valve ribbon openings as if they were in line.

The magnetic flux for the ribbon air-gap is supplied by two permanent magnets made of "Alnico." This material is an alloy of iron, aluminum, cobalt, and nickel, and has the characteristic of very high retentivity along with high magnetomotive force, the latter determining the value of light-valve sensitivity.

Stringing and adjusting the ribbons of this new type of light-valve is reasonably simple. As already mentioned, separate screw adjustments are provided for spacing and tuning each ribbon independently, even after the light-valve is completely assembled.

The entire light-valve and double-magnet assembly is quite compact, as shown in Fig. 7. The overall dimensions of the unit are 1.4 inch wide, 1 inch thick, and 4 inches long overall. The overload point is about 9 db. above 0.006 watt, and the closure current approximately 170 milliamperes per ribbon. Field tests under actual operating conditions have shown this type of valve to be very constant in performance and easy to maintain in proper adjustment.

A BASICALLY NEW FRAMING DEVICE FOR 35-MM PROJECTORS*

H. A. DEVRY**

The motion picture projection machine has undergone fewer radical changes and improvements than perhaps any other mechanical electrical device in daily use by so many thousands. This is due partly to the fact that the old designers did a very good job so that radical improvements seemed improbable. However, any mechanical contrivance or machine that has suffered no changes except refinements in 15 to 20 years can hardly be expected to be a really modern machine.

With this thought in mind we have developed not only an improvement, at least so far as simplicity and cost are concerned, but quite a novel and unique application of a silent chain drive, which so far as we or the manufacturer of the chain know, has not been made before.

The feature of the device lies in changing the course of the chain without affecting the shutter. Both shutter and sprocket are motivated by the same chain (Fig. 1).

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received February 25, 1938.

** H. A. DeVry Corp., Chicago, Ill.

Our original idea of about three years ago was to frame the intermittent sprocket straight up and down below the aperture, which worked out very satisfactorily in hundreds of machines in all parts of the world. Another advantage of the first model was that by removing three screws the entire intermittent assembly can be exchanged or replaced practically between reels.

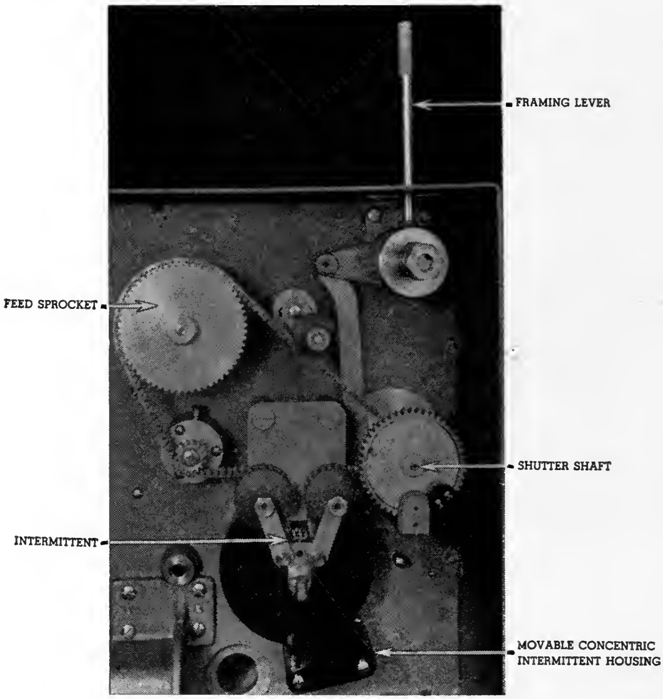


FIG. 1. Framer in neutral position; moving lever to the right moves film up, and *vice versa*.

The only disadvantage of this framing method, if it can be called a disadvantage, was that when the intermittent sprocket was positioned all the way down (which, of course, is not necessary when threaded by a good projectionist), it left a space of the height of one frame between the aperture plate and the sprocket, which might cause some film to buckle slightly at that point by slightly overthrowing the film.

When this was called to our attention this objection was overcome by a slightly different application of the same basic principle. The revolving intermittent sprocket framer was arranged as in Fig. 2. Note that at the point indicated by the arrow, there is no possibility of film buckling, as the sprocket always remains close to the gate, regardless of the position of the film.

This particular type of chain drive thus achieves freedom from film buckling while framing, and also removes the possibility of the shutter's being put out of synchronism with the film. In addition, the cost of manufacture is cut to the minimum.

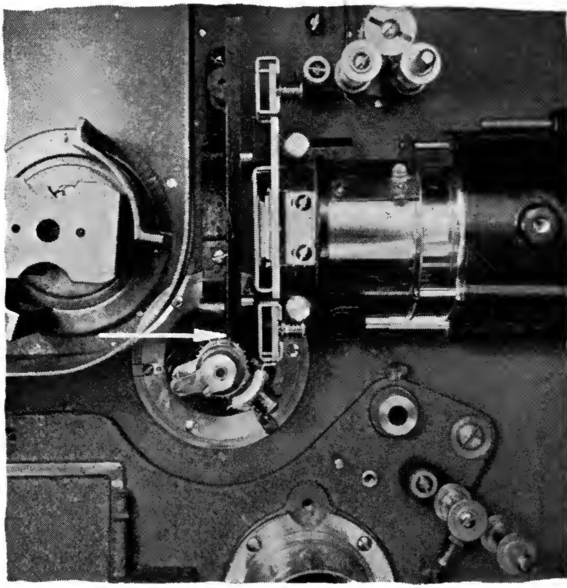


FIG. 2. Showing arrangement of intermittent sprocket framer.

The advantage of the silent chain drive is perhaps best attested by the fact that the Ford Motor Company, like Cadillac, Chrysler, and other automobile manufacturers, use silent chains for driving cam shafts, which is perhaps the most particular job on an automobile engine.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in those magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

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18 (June, 1938), No. 6

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Features of 1939 Receivers (pp. 15–18).	D. D. Cole, G. G. Gerlach, and W. P. Short

Electronics

11 (June, 1938), No. 6

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Rectifier Filter Design (pp. 28–30).	H. J. Scott
A Sound Effects Machine with High Impedance Mixing (pp. 56, 58).	M. J. Weiner

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10 (June, 1938), No. 5

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Optical Printer Handy Andy (pp. 14, 16).	L. Dunn
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Flimmern und Bildwandbeleuchtung (Flicker and Screen Illumination) (pp. 141–143).	H. Naumann
Der Farbenausgleich zwischen Szenen und Szenenteilen beim Farbenfilm (Color Balancing between Scenes and Parts of Scenes in Color-Films) (pp. 143–144).	L. Kutzleb
Über die Berechnung photographischer Belichtungen (Computation of Photographic Exposure) (pp. 145–148).	G. Albrecht

Quecksilberdampflampen hoher Leuchtdichte (High-Intensity Mercury Vapor Lamps) (pp. 148–152). O. HOPCKE AND W. THOURET

Ein neuer Projektor für 8-Mm.-Film (New 8-Mm. Projector (Dralowid)) (p. 153).

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Die Bedeutung des elektrischen Belichtungsmessers für die Kinematographie I (Importance of Electrical Exposure Meters for Motion Picture Photography—I) (pp. 705–707). H. C. OPFERMANN

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9 (May, 1938), No. 89

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11 (June, 1938), No. 124

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The London Television Service (pp. 329–331). T. C. MACNAMARA AND D. C. BIRKINSHAW

Mihaly-Traub Television (p. 336).

The Receiving Aerial and Reception Fidelity (pp. 342–343). S. W. SEELEY

BOOK REVIEW

Motion Picture Sound Engineering: A symposium of papers on Studio Sound Recording and Theater Sound Reproducing Equipment and Practice, *Academy of Motion Picture Arts & Sciences* (Taft Building, Hollywood, Calif.), $4.00.

This book results from courses in motion picture sound engineering conducted during 1936 and 1937 by the Research Council of the Academy of Motion Picture Arts & Sciences, the lecturers being the qualified representatives of the major sound departments. There are thirty-nine chapters, of which the first ten relate to the practice of sound recording in studios and sound reproducing in theaters, while the succeeding chapters are concerned with transmission circuits and electromagnetic theory.

After an excellent introductory chapter on the basis of motion picture sound, the text proceeds to discuss the nature of sound, the types of film recording in use, the acoustic instruments used for sound pick-up and for monitoring, the mechanical and optical features of film propulsion and scanning, and the circumstances of theater sound reproduction. There are chapters explaining film processing and the artifices of noise-reduction as well as the more recent methods of recording, such as push-pull, squeeze-track, and pre- and post-equalization. In the discussion of these new methods there is much that, while not yet classical, discloses the processes of advance in sound picture engineering.

While the text describes most of the steps currently employed in film recording and processing, there are a few omissions as, for example, in the chapter on film processing there is no reference to the useful delta-db. test in variable-density work or of the intermodulation tests regularly used to determine the optimal processing of variable-width sound-track.

Although the book is devoted to photographic methods, there might well be a place for a short discussion of disk recording and reproduction, which has a definite place for play-back and pre-scoring. The references to loud speakers likewise might well be amplified to include descriptions of the various types of receivers, horns, and baffles in commercial use.

The earlier chapters, *I* to *X*, are descriptive of apparatus and processes of interest to the general reader, telling him what the sound engineer has to do and how he does it. The subsequent chapters are for the electrical engineer, with particular reference to the mathematical problems of the sound engineer. They apply to the design rather than the operation of sound equipment.

The Academy of Motion Picture Arts & Sciences is to be congratulated upon having sponsored the training courses that resulted in the publication of such a useful compilation of information dealing with the relatively new science of sound recording and reproduction.

H. G. Knox

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MRS. A. J. BRADFORD	MRS. E. H. FORBES	MRS. R. L. RUBEN
MRS. K. BRENKERT	MRS. W. M. HARRIS	MRS. G. J. SKIMIN

Headquarters

The Headquarters of the Convention will be at the Hotel Statler, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, who are now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to SMPE delegates and friends, European plan, will be as follows:

One person, room and bath	$3.00 to $6.00
Two persons, room and bath	5.00 to 8.00
Two persons (twin beds), room and bath	5.50 to 9.00
Three persons, room and bath	7.50 to 10.50
Parlor suite and bath, for one	8.50 to 11.00
Parlor suite and bath, for two	12.00 to 14.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. Local railroad ticket agents should be consulted as regards train schedules, and rates to Detroit and return.

The following special rates have been arranged for SMPE delegates who motor to the Convention, at the National-Detroit Fireproof Garage (the Hotel Statler's official garage), Clifford and Elizabeth Streets, Detroit: Self-delivery and pick-up, 12 hours, $0.60; 24 hours, $1.00; Hotel-delivery and pick-up, 24 hours, $1.25. Special weekly rates will be available.

Technical Sessions

An attractive and interesting program of technical papers and presentations is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the Large Banquet Room of the Hotel.

Registration and Information

Registration headquarters will be located at the entrance of the Large Banquet Room, where members of the Society and guests are expected to register and receive their badges and identification cards for admittance to the sessions and film

programs. These cards will be honored also at the Fox Detroit Theater, through the courtesy of Mr. David Idzol, and special passes will be furnished to registered members and guests for admittance to the Michigan United Artists and Palms-State Theaters, through the courtesy of the United Detroit Theaters Corporation.

Informal Luncheon and Semi-Annual Banquet

The usual Informal Luncheon will be held at noon of the opening day of the Convention, October 31st, in the *Michigan Room* of the Hotel. On the evening of Wednesday, November 2nd, the Semi-Annual Banquet of the Society will be held in the Grand Ballroom of the Hotel at 8 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Tours and Points of Interest

In view of the fact that this Convention will be limited to three days, no recreational program or tours have been arranged. However, arrangements may be made for visits to the Jam Handy plant and to other points of technical and general interest in Detroit on the day following the Convention, namely, November 3rd. Arrangements for such trips may be made at the registration headquarters of the Convention.

In addition to being a great industrial center, Detroit is also well known for the beauty of its parkways and buildings, and its many artistic and cultural activities. Among the important buildings that one may well visit are the Detroit Institute of Arts; the Detroit Historical Society Museum; the Russell A. Alger House, a branch of the Detroit Institute of Arts; the Cranbrook Institutions; the Shrine of the Little Flower; and the Penobscot Building.

At Greenfield Village, Dearborn, are grouped hundreds of interesting relics of early American life, and there also is located the Edison Institute, established by Henry Ford in memory of Thomas A. Edison.

On the way to Greenfield Village is the Ford Rotunda, a reception hall for visitors to the Ford Rouge Plant. Here are complete reproductions and displays of motorcar design, and representations of the famous highways of the world, from Roman days to modern, are on the grounds surrounding the building.

The General Motors Research Building and Laboratory, located on Milwaukee Avenue, will be of particular interest to engineers visiting the City.

Various trips may be taken from Detroit as a center—to Canada, by either the Ambassador Bridge or the Fleetway Tunnel; to Bloomfield Hills, a region of lakes; Canadian Lake Erie trip from Windsor, Ontario; to Flint, Michigan, another center of the automotive industry; to Milford, General Motors' Proving Grounds; and to the Thumb of Michigan Resort Beaches. The City contains also a number of beautiful parks and golf courses.

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THE THEORY OF THREE-COLOR PHOTOGRAPHY*

A. C. HARDY**

Summary.—*All methods of three-color photography are the outgrowth of a suggestion made in 1855 by Clerk Maxwell, the illustrious British physicist. The method that he suggested would now be classed as an additive process, since the final reproduction was effected by projecting three lantern-slides in register on the same screen; one lantern being supplied with a red filter, one with a green filter, and one with a blue filter. Maxwell suggested further that these lantern-slides be prepared from three negatives, each negative being exposed through the same filter that was to be used in projecting the corresponding lantern-slide. An extension of Maxwell's reasoning to subtractive processes leads to the conclusion that the dyes used in the production of the positive images should each be complementary in color to the corresponding taking filter.*

Despite Maxwell's intimation that his process was theoretically incapable of perfect reproduction, the basic features of Maxwell's reasoning have been incorporated into the commonly accepted theory of color reproduction. The recent progress in the science of colorimetry has made it possible to investigate the relation that should obtain between the characteristics of the taking filters and the colors of the reproduction primaries. Such an investigation shows that the taking filters required for perfect reproduction have characteristics that are very different from those in common use.

The paper is concerned with the establishment of the conditions that lead to faithful reproduction by any three-color process. Examples of the application of these fundamental conditions are given for both additive and subtractive processes.

In another paper[1] presented at the Washington Convention of the Society, D. L. MacAdam showed that colorimetry has now acquired the status of an exact science. The motion picture film that he exhibited demonstrated how this science can be employed to test the faithfulness of any process of color photography. In this application, colorimetry plays a role not unlike that of the calipers in the hands of a machinist who undertakes to duplicate a mechanical part in a machine shop. By means of the calipers, the machinist is able to compare the dimensions of the reproduction with the corresponding dimensions of the original.

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received June 22, 1938.

** Massachusetts Institute of Technology, Cambridge, Mass.

The purpose of this paper is to indicate the application of the science of colorimetry to the theory of color photography. This may be likened to the design of machinery that will produce automatically the result that the machinist achieves by trial and error. More specifically, this paper is concerned with the determination of the characteristics of three color filters which, when used as taking filters in a three-color process, will enable negatives to be made that will control the reproduction primaries properly at every point of the reproduction.

Let the subject contain an area whose color can be characterized by the statement that the light received from this area by the camera lens has a spectral distribution of energy E. The tristimulus values of this area are[1]

$$X = \int_0^\infty E\bar{x}d\lambda, \tag{1a}$$

$$Y = \int_0^\infty E\bar{y}d\lambda, \tag{1b}$$

$$Z = \int_0^\infty E\bar{z}d\lambda, \tag{1c}$$

where $\bar{x}$, $\bar{y}$, and $\bar{z}$ are the tristimulus values of unit amounts of the spectrum colors in the colorimetric system employed.

Suppose the tristimulus values of unit amounts of the primaries that are mixed to form the positive reproduction are $X_rY_rZ_r$, $X_gY_gZ_g$, and $X_bY_bZ_b$, respectively. Then, if an area of the reproduction contains r units of the red primary, g of the green, and b of the blue, the tristimulus values of this area are

$$X' = rX_r + gX_g + bX_b, \tag{2a}$$

$$Y' = rY_r + gY_g + bY_b, \tag{2b}$$

$$Z' = rZ_r + gZ_g + bZ_b. \tag{2c}$$

If this area of the reproduction is to evoke the same visual sensation as the area of the subject characterized by the energy distribution E, the necessary condition is

$$X' = X, \tag{3a}$$

$$Y' = Y, \tag{3b}$$

$$Z' = Z. \tag{3c}$$

Over a wide range of brightness level, the reproduction would be entirely satisfactory if the tristimulus values of the reproduction are

proportional, but not necessarily equal, to those of the corresponding area of the original.

The first step in virtually all methods of three-color reproduction is the making of three color-separation negatives (or the equivalent). To simplify the mathematical expressions, let the effective spectral sensitivity of the three negative emulsions be represented by S_r, S_g, and S_b, respectively, it being understood that the effective sensitivity at each wavelength is the product of the inherent sensitivity of the emulsion and the transmittance of the filter used in conjunction therewith. When these three emulsions are exposed to the area of the subject characterized by a spectral distribution of energy E, the three exposures are proportional, respectively, to

$$\Sigma_r = \int_0^\infty ES_r d\lambda, \tag{4a}$$

$$\Sigma_g = \int_0^\infty ES_g d\lambda, \tag{4b}$$

$$\Sigma_b = \int_0^\infty ES_b d\lambda. \tag{4c}$$

When one follows the conventional procedures, each exposure determines the amount of one of the reproduction primaries. If the conditions for tone reproduction are satisfied,

$$r = k_r\Sigma_r, \tag{5a}$$

$$g = k_g\Sigma_g, \tag{5b}$$

$$b = k_b\Sigma_b. \tag{5c}$$

These five sets of equations may be combined algebraically to yield the following equations:

$$k_rX_r\int_0^\infty ES_r d\lambda + k_gX_g\int_0^\infty ES_g d\lambda + k_bX_b\int_0^\infty ES_b d\lambda = \int_0^\infty E\bar{x}d\lambda, \tag{6a}$$

$$k_rY_r\int_0^\infty ES_r d\lambda + k_gY_g\int_0^\infty ES_g d\lambda + k_bY_b\int_0^\infty ESbd\lambda = \int_0^\infty E\bar{y}d\lambda, \tag{6b}$$

$$k_rZ_r\int_0^\infty ES_r d\lambda + k_gZ_g\int_0^\infty ES_g d\lambda + k_bZ_b\int_0^\infty ES_b d\lambda = \int_0^\infty E\bar{z}d\lambda, \tag{6c}$$

which define the necessary and sufficient conditions that *one* color in the subject be reproduced correctly. Inspection of these equations reveals that one color in the subject may be reproduced correctly in an infinite number of ways. In other words, regardless of the form of the functions S_r, S_g, and S_b or the tristimulus values of the repro-

duction primaries, the constants may always be chosen in such a manner that equations *6* will be satisfied for one color of the subject.

The usual desideratum in color photography is to reproduce correctly *all* colors of the subject that lie within the realizable color gamut. This means in mathematical language that equations *6* must be satisfied simultaneously, regardless of the form of the function E. This will be true if at every wavelength

$$k_rX_rS_r + k_gX_gS_g + k_bX_bS_b = \bar{x}, \tag{7a}$$

$$k_rY_rS_r + k_gY_gS_g + k_bY_bS_b = \bar{y}, \tag{7b}$$

$$k_rZ_rS_r + k_gZ_gS_g + k_bZ_bS_b = \bar{z}. \tag{7c}$$

Since only relative values of S_r, S_g, and S_b are required in practice, equations *7* can be written more simply in terms of the trichromatic coefficients of the reproduction primaries rather than in terms of their tristimulus values. When this is done, the fundamental conditions for exact color reproduction by a three-color process become

$$x_rS_r + x_gS_g + x_bS_b = \bar{x}, \tag{8a}$$

$$y_rS_r + y_gS_g + y_bS_b = \bar{y}, \tag{8b}$$

$$z_rS_r + z_gS_g + z_bS_b = \bar{z}. \tag{8c}$$

To avoid misunderstanding, it may be added that these conditions are perfectly general in the sense that the colors of the subject may be either real or imaginary. Likewise, the reproduction primaries may be either real or imaginary. In a practical process, the reproduction primaries are real, and negative amounts of the primaries can not be employed. This limits the realizable color gamut, but it in no way alters the fundamental requirements which must be fulfilled by any three-color process, real or imaginary.

The application of equations *8* to additive processes is immediately evident. In such processes, the trichromatic coefficients of the primaries are easily ascertained by the application of procedures that are well standardized in the field of colorimetry. Likewise, the tristimulus values of unit amounts of the spectrum colors are well known for a normal observer.[2] Equations *8* can thus be solved for the values S_r, S_g, and S_b at each wavelength. Then, knowing the spectral sensitivities of the emulsions to be employed, the characteristics of the required color filters can be computed.

The application of these equations to subtractive processes is not so obvious, largely because of the uncertainty concerning the values that should be used for the trichromatic coefficients of the primaries.

In an ideal subtractive process, each dye absorbs light uniformly in a spectral region that is not absorbed by the other two. Thus, each reproduction primary is determined by the color of the light absorbed by one of the three dyes. In this ideal case, it is a simple matter to determine the trichromatic coefficients of the primaries. By substituting their values in equations *8*, the required spectral sensitivities of the color-separation negatives can readily be determined.

With the dyes that are available for use in subtractive processes, it is impossible to assume that, at every wavelength, the absorption of light is produced by the action of one dye alone. Instead, the primaries of subtractive processes must be determined under conditions that take account of the actual behavior of the dyes. A method by which this can be accomplished will be clear from the spectrophotometric curves shown in Fig. 1. It will be noted that curve F is the same in all three illustrations. This curve represents the spectral transmittance curve of a piece of color-film whose color is such that it would produce a light flesh tint when projected upon the screen. A flesh tint was chosen as the color of reference partly because of its importance in color photography and partly because it is not far removed from the center of the realizable color solid.

Now let another piece of film be prepared under identical conditions except that the concentration of the red-absorbing (blue-green) dye is slightly reduced. The spectral transmittance curve of this film is represented by curve R. It will be seen that reducing the concentration of the red-absorbing dye has brought about an increase in the amount of red light transmitted by the film, as would be expected. More exactly, curve R', which is obtained by subtracting the ordinates of curve F from those of curve R, indicates the spectral distribution of the light controlled by the red-absorbing dye, assuming the projection source to emit equal amounts of energy throughout the spectrum. The trichromatic coefficients computed from this curve, after modification by the energy distribution of the source, are the required values of x_r, y_r, and z_r. By repeating the experiment of varying the concentration of one dye at a time, it is possible to find the trichromatic coefficients corresponding to curves G' and B'. This procedure evidently determines the trichromatic coefficients of the primaries, which are needed for substitution in equations *8*.

When such a test is performed with the dyes that are now available, the trichromatic coefficients of the primaries are found to depend to some extent upon the color selected as the color of reference. Since

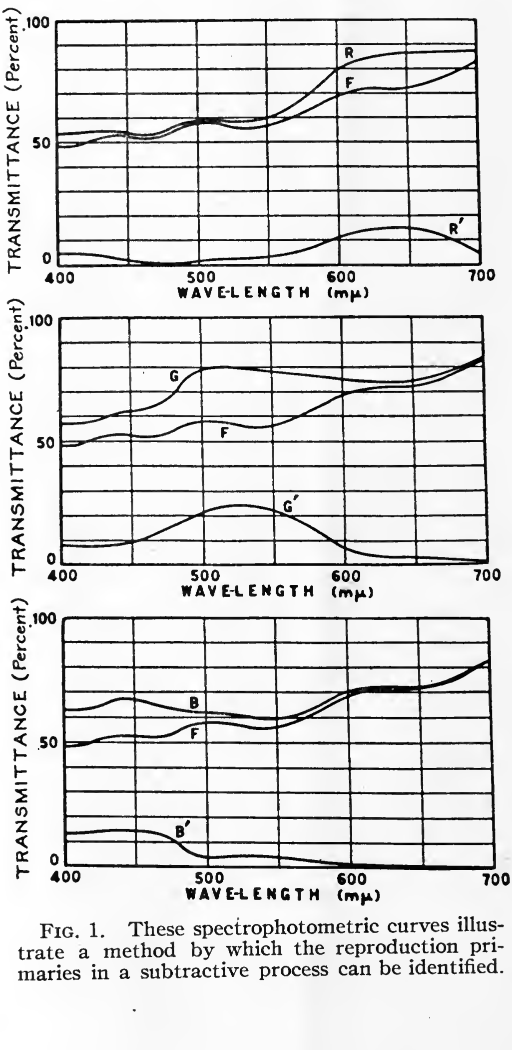

FIG. 1. These spectrophotometric curves illustrate a method by which the reproduction primaries in a subtractive process can be identified.

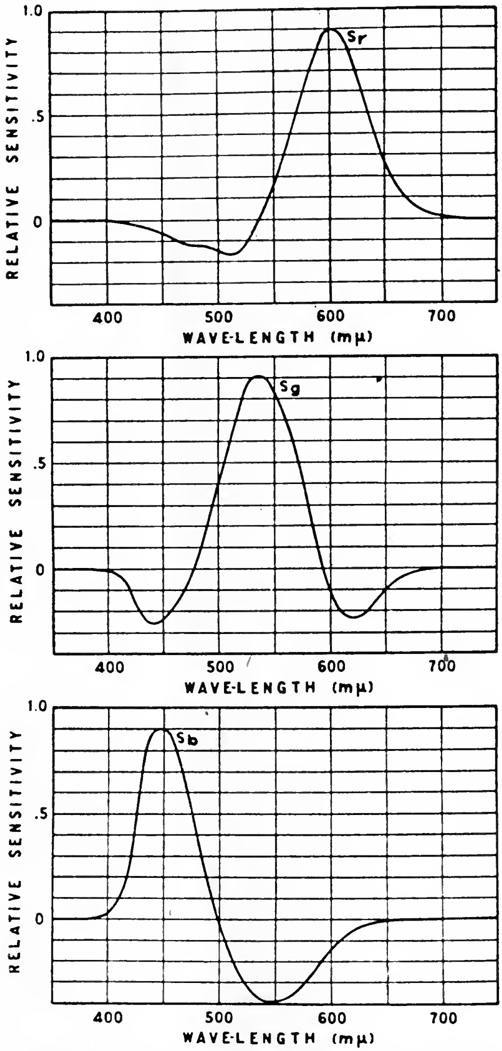

FIG. 2. These curves indicate the relative spectral sensitivity of the three emulsions to be used in making three-color separation negatives that will control properly the reproduction primaries identified in Fig. 1.

a change in the trichromatic coefficients of the primaries should theoretically be compensated by a modification in the characteristics of the taking filters, the most useful expedient in practice is to determine the trichromatic coefficients of the primaries for a color of reference near the center of the realizable color solid. The various constants of the system may then be chosen in such a manner as arbitrarily to make the rendition correct for certain colors which should preferably lie near the outside of the realizable color solid. In this way, the errors in the color rendition are reduced everywhere to approximately their minimum values.

If one assumes a projection source having, for example, an energy distribution corresponding to that of the I.C.I. Illuminant *C*, the trichromatic coefficients calculated from curves R', G', and B' of Fig. 1 are as shown in Table I.

TABLE I

Red Primary	Green Primary	Blue Primary
$x_r = 0.4969$	$x_g = 0.1985$	$x_b = 0.1847$
$y_r = 0.3346$	$y_g = 0.4423$	$y_b = 0.1265$
$z_r = 0.1685$	$z_g = 0.3592$	$z_b = 0.6889$

When these values are substituted in equations *8*, the values of S_r, S_g, and S_b are found to be as shown in Fig. 2. It will be recalled that the ordinates of these curves represent the effective spectral sensitivity (on a relative scale) of the three photographic emulsions that will result in the color-separation negatives that will properly control the reproduction primaries identified by the method illustrated in Fig. 1. It will be noted that the required spectral sensitivity is less than zero at certain wavelengths, an effect that can not be achieved directly by means of color filters. In another publication,[3] numerous suggestions for the practical realization of the required negative values of the spectral sensitivity have been made. One method comprises making two negatives, the spectral sensitivity of each being such that, when the exposure of one is photographically subtracted from the exposure impressed upon the other, the result will simulate one of the curves in Fig. 2. Hence, by making a total of six negatives, the three primaries can be controlled properly.

Although the above expedient is useful as an illustration of the application of the rigorous theory, a camera designed to expose six negatives simultaneously would be quite impracticable. Three negatives may be made to suffice, however, by abandoning the assumption

incorporated in equations *5*. Instead, let it be assumed that the amount of the red primary is to be made dependent to some extent upon the exposure received by all three color-separation negatives. If a similar assumption is made with respect to the green and blue primaries, equations *9* are an expression of the proposed technic.

$$r = k_1\Sigma_r + k_2\Sigma_g + k_3\Sigma_b, \tag{9a}$$

$$g = k_4\Sigma_r + k_5\Sigma_g + k_6\Sigma_b, \tag{9b}$$

$$b = k_7\Sigma_r + k_8\Sigma_g + k_9\Sigma_b. \tag{9c}$$

The practical realization of the technic indicated by these equations involves controlling the red primary, for example, by means of a photographic image of the subject that is a composite record of the exposure of the red negative, the exposure of the green negative, and the exposure of the blue negative. The extent to which each exposure is weighted by this record is determined by the magnitude of the constants k_1, k_2, and k_3. When one of the constants is less than zero, a positive image rather than a negative image is to be employed in making the composite record. Care must also be taken that the characteristics of the photographic materials are substantially linear, as in the toe method of sound recording, in order that a true addition or subtraction of exposures may be effected.

With this understanding of the proposed technic, let equations *9* be substituted in the previous development instead of equations *5*. The conditions for correct color rendering are then found to take the form

$$K_1S_1 + K_2S_2 + K_3S_3 = \bar{x}, \tag{10a}$$

$$K_4S_1 + K_5S_2 + K_6S_3 = \bar{y}, \tag{10b}$$

$$K_7S_1 + K_8S_2 + K_9S_3 = \bar{z}, \tag{10c}$$

where the constants in the above equations (indicated by capital letters) have the following values:

$$\begin{aligned}
K_1 &= k_1X_r + k_4X_g + k_7X_b,\\
K_2 &= k_2X_r + k_5X_g + k_8X_b,\\
K_3 &= k_3X_r + k_6X_g + k_9X_b,\\
K_4 &= k_1Y_r + k_4Y_g + k_7Y_b,\\
K_5 &= k_2Y_r + k_5Y_g + k_8Y_b,\\
K_6 &= k_3Y_r + k_6Y_g + k_9Y_b,\\
K_7 &= k_1Z_r + k_4Z_g + k_7Z_b,\\
K_8 &= k_2Z_r + k_5Z_g + k_8Z_b,\\
K_9 &= k_3Z_r + k_6Z_g + k_9Z_b.
\end{aligned}$$

Equations *10* are of the same form as equations 7, and can be used in the same manner. In this case, the spectral sensitivities, S_r, S_g, and S_b, may be everywhere positive and are therefore readily realizable in practice. Those familiar with the concepts of colorimetry will recognize that this technic involves, in effect, the preparation of a set of three negatives which would properly control a set of imaginary reproduction primaries. By making the additive and subtractive combinations indicated by equations *9*, a new set of negatives can be prepared that will properly control the reproduction primaries employed in any process, additive or subtractive. In the application of this technic to subtractive processes, the number of constants is so great that the reproduction may arbitrarily be made correct at several points within the boundaries of the realizable color solid.

It may be added by way of conclusion that the requirements of the theory herein set forth are inescapable. They are the direct consequence of the characteristics of the visual processes of the human observer. No three-color process can ever duplicate the energy distribution of each point of the subject, but it can be made to duplicate the visual effect, provided the necessary conditions are satisfied. That the conventional color separation-negatives do not properly control the reproduction primaries has been given tacit recognition by the empirical attempts at "correction," such as *masking*. Although such methods of correction are incapable of satisfying the conditions for perfect color reproduction, the improvement resulting from their use seems to indicate the desirability of employing the type of correction that a rigorous analysis of the problem prescribes.

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DISCUSSION

MR. KELLOGG: Does your statement that we should be able to get accurate reproduction with the existing primaries presuppose that you do not in any case have to deal with colors above a certain purity?

MR. HARDY: This mathematical treatment takes no account of whether the color is realizable in practice or not. If the color is one falling outside the gamut

that can be achieved with positive amounts of the three primaries, the mathematics would simply indicate the fact by a change in algebraic signs. In practice, one does not know how to use less than zero grams of a certain dye in making the color reproduction. Mathematically, on the other hand, the actual number of grams required to reproduce a color outside the existing gamut can be calculated as easily as in the case of a realizable color.

MR. KELLOGG: You said quite definitely you could make perfect reproduction with existing primaries.

MR. HARDY: One can theoretically achieve perfect reproduction within the permissible gamut. Outside the permissible gamut, negative amounts of the primaries must be used.

MR. KELLOGG: We can not do that.

MR. HARDY: That is correct; but I wish to emphasize that that assumption of realizability does not enter into the derivation of the equations.

MR. MAURER: Mr. Hardy has shown that the characteristics of the filters to be used on the three-color camera, in order to obtain perfect color reproduction with the assumed set of subtractive primaries, are characteristics that are not realizable in practice, for the reason that negative transmission values are required at certain wavelengths. Have any studies been made indicating whether or not it would be possible to choose other sets of subtractive primaries, perhaps having smaller regions of overlap, that would permit the use of taking filters not having these regions of negative transmission?

MR. HARDY: These linear transformation equations show that one element in the reproduction cycle must be imaginary. You might make the observer imaginary, but I do not think that would be good for the box-office. If you want to design the system for a human observer as he exists today, then either the reproduction primaries must be imaginary or the filters must be imaginary. I think the practical solution is to use real primaries and to employ procedures that simulate the effect of imaginary filters.

MR. MAURER: My point was merely that today rapid progress is being made in the production of new synthetic dyes, and possibly if a theoretical reproduction dye were indicated, synthetic work would eventually produce that dye.

MR. HARDY: I think not. The requirements would be that the dyes used in making the reproduction transmit less than no light at certain wavelengths.

MR. KELLOGG: The tricolor stimulus values as given in the "Handbook of Colorimetry" and elsewhere are based upon three specified monochromatic primaries. I understand that you can choose and define the primaries in various ways, but a certain three are generally taken as the reference standard. As I recall, there is only one curve that dips much below zero, and that is the red. You showed here a set of equivalent curves for the primaries you were last discussing, in which each of the curves show a big dip, down almost to 40 per cent negative. Do those represent the theoretically required amounts of the various colored lights in view of the fact that they were not monochromatic but each had a rather wide spread?

MR. HARDY: The primaries in the colorimeter system that Mr. MacAdam and I both have employed here are not monochromatic. I would rather not go into the exact nature of the primaries in the system, for the reason that the primaries of the system of colorimetry are not involved in the results I reported. Color-

imetry enters into this discussion merely as a means for expressing the fact that the color of the reproduction is to be like that of the original. The primaries used in the colorimetric system cancel out, provided the same primaries are employed in both cases.

MR. KELLOGG: But were not those curves for a specific set of primaries?

MR. HARDY: The filter transmission curves were for the specific set that had been exhibited in the preceding slides. I showed how, in a typical subtractive process, to identify the primaries which were energy distributions in the red, green, and blue; and then, using those primaries, showed what the filter curves must be if those primaries are to be properly controlled in the reproduction.

MR. GOLDEN: We all know that the lighting in the theater auditorium has an effect upon the projected screen picture. How does the color theory apply to this effect?

MR. HARDY: When I talk about color reproduction in the graphic arts and am asked, "What happens when you have three inks and they happen to be printed upon paper stock of different colors?" my answer is that you make the print on the stock you are going to use before you figure out what filters should be employed.

Now, of course, if different theaters use lighting systems that are sufficiently different, then it will be difficult to obtain release prints that look right in all theaters. It is possible to select one theater, make the tests under the conditions obtaining in that theater, and design the cycle so that it will be exactly correct. For other theaters modifications should theoretically be made at some point in the technic.

MR. GOLDEN: Don't you think we should go a step farther, and standardize the lighting of the theaters of the country?

MR. HARDY: Yes. As the art advances, more and more attention should properly be paid to such questions.

THE FUNDAMENTALS OF COLOR MEASUREMENT*

D. L. MacADAM**

Summary.—*The modern science of color measurement had its origin in the researches of Helmholtz, Maxwell, and Grassmann in the years from 1852 to 1855. This science found no important practical application until the opening of the twentieth century when the (F. E.) Ives colorimeter was applied to the measurement and specification of the colors of practical illuminants. In 1922 the Optical Society of America, through its Committee on Colorimetry, recommended data and technics for color measurement which were immediately adopted throughout the world, replacing numerous unrelated, and often inconsistent, technics that had been developed to meet the insistent demands of various industries for color specifications. A set of data based upon the most recent researches was recommended by the International Commission on Illumination in 1931, and these more satisfactory data have in turn replaced the data and extended the unification of methods which orginated with the O.S.A. Report of 1922.*

Standard I.C.I. color specifications can be computed from spectrophotometric data. The fundamental relations that are used to define the quantities in terms of which colors are specified are most concisely expressed in mathematical formulas, which will be simply explained. As a matter of fact, short cuts based upon the standard I.C.I. 1931 data have been developed in the past few years so that no acquaintance with any mathematics other than ordinary arithmetic is now necessary for the performance of any of the essential operations encountered in standard color measurement. A typical example will be exhibited, and the interpretation of the results in terms of the dominant wavelength, purity, and brightness will be made clear by use of the chromaticity diagram. The conditions required in order that the colors of two samples shall match under some definite illuminant are that the three quantities in terms of which the colors are specified must be the same for the two samples.

The purpose of this paper is to describe a practical method for measuring colors. Consequently, the basic visual experiments that justify the use of the method will be mentioned only briefly. Such experiments are based upon the familiar fact that almost all the colors encountered in nature and in industry can be matched by mixtures of any reasonable set of three primary colors of suitable intensities.

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** Eastman Kodak Co., Rochester, N. Y.

In 1930 the International Commission on Illumination adopted the results of accurate and extensive experiments of this kind and recommended a method, based upon normal human vision, by which the intensities of three mathematically convenient primary colors can be computed from the distribution of energy in the spectrum of the color to be measured. The standard primary colors can not be secured

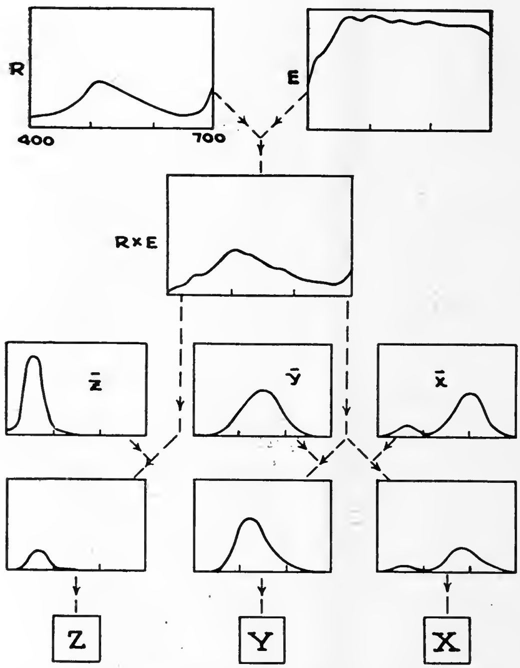

Fig. 1. Diagrammatic representation of a method for computing the tristimulus values X, Y, Z.

in any instrument, but, nevertheless, the computed intensities are very convenient specifications of color. For instance, if the intensities of the standard primaries computed from the energy distribution of two sample colors are the same for the two colors, then these colors will appear identical.

Fig. 1 illustrates the principle of the method of computation recommended by the International Commission. The curve in the upper left corner of the diagram represents the reflectance of a green object for every wavelength of the visible spectrum, from violet at the left

to red at the right. Such a curve must be determined for every sample whose color is to be measured. The optical instrument used for the determination of this curve is called a spectrophotometer. There are many varieties of spectrophotometers, some of which employ human observers, while others use photoelectric cells.

The color of the sample depends upon the reflectance curve and also upon the distribution of energy throughout the spectrum of the light-source that illuminates the sample. The curve in the upper right corner of Fig. 1 represents the distribution of energy in the spectrum of a *standard* source of artificial daylight. Such a distribution curve must be known for each illuminant with reference to which colors are to be measured. The International Commission on Illumination has published such data for three light-sources which are defined as standards for color measurement. Data for other light-sources have been published in many other places. When satisfactory data on the distribution of energy in the spectrum of a desired light-source are not available, the data must be obtained by use of the methods of spectroradiometry. These data can not be determined with accuracy outside of a few elaborately equipped laboratories where a specialty is made of such measurements.

The energy reflected by the sample at a given wavelength is the product of the values at that wavelength indicated by the upper two curves (Fig. 1), and is shown in the curve just below. The three color-mixture functions adopted by the International Commission on Illumination are represented by the curves labelled $\bar{x}$, $\bar{y}$, $\bar{z}$. Light of each wavelength reflected from the sample contributes to each primary of the color specification an intensity proportional to the product of the energy and the corresponding color-mixture function. The three curves resulting from these multiplications throughout the visible spectrum are shown in the lowest set of diagrams (Fig. 1). The areas under the curves are the totals of the contributions at every wavelength throughout the spectrum to the intensities X, Y, Z, of the standard primaries necessary to match the sample color. These intensities are called the tristimulus values of the color.

Mathematically this procedure is represented by the integrals

$$X = \int R \cdot E \cdot \bar{x} \cdot d\lambda, \qquad Y = \int R \cdot E \cdot \bar{y} \cdot d/\lambda, \qquad Z = \int R \cdot E \cdot \bar{z} \cdot d\lambda$$

These integrals mean nothing more nor less than the arithmetical procedures represented in Fig. 1.

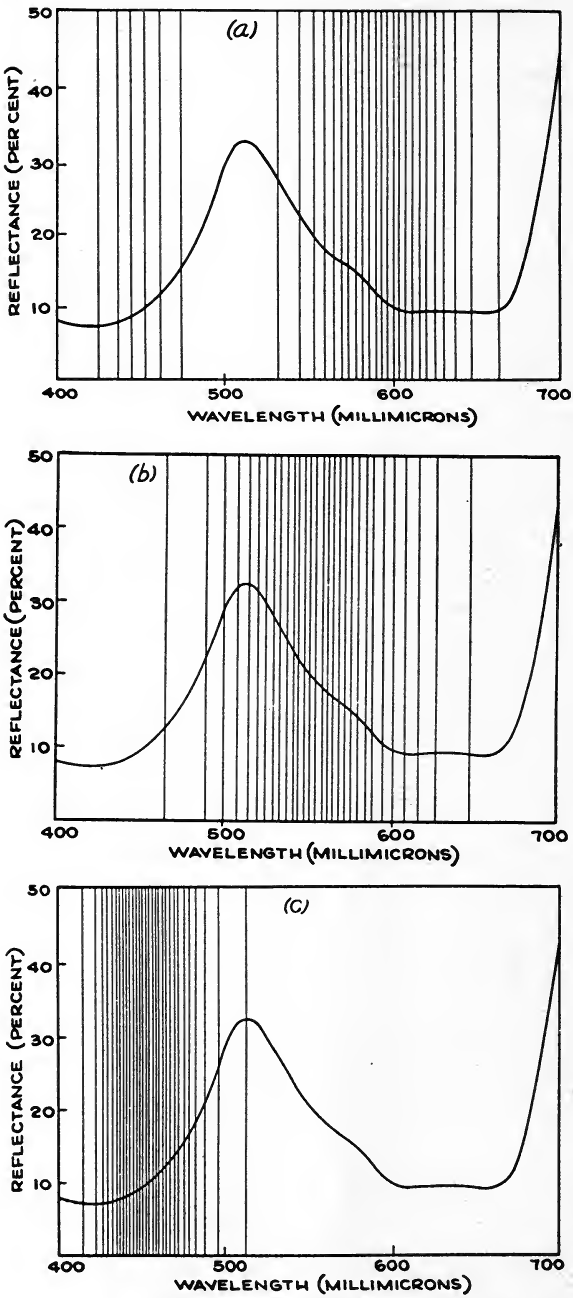

FIG. 2. Example of the selected-ordinate method of computing tristimulus values: (*Upper*) X, (*Center*) Y, (*Lower*) Z.

Another and more rapid method of computing the tristimulus values has been devised. This is known as the selected-ordinate method and consists in averaging the values that the reflectance curve of each sample attains at certain wavelengths, which have been published. The thirty vertical lines in Fig. 2(*a*) are drawn at the wavelengths at which the reflectances should be read from the curve of the sample, and averaged in order to compute the tristimulus value X. The values of the reflectance at the wavelengths indicated by the vertical lines in Fig. 2(*b*) should be averaged in order to compute the tristimulus value Y. Finally, the values read from the curve of the sample of the wavelengths shown in Fig 2(*c*) should be averaged to compute the tristimulus value Z. Transparent templates, on which lines are ruled corresponding to the vertical lines in Figs. 2(*a*), (*b*), and (*c*) can be prepared, to be placed temporarily over any spectrophotometric curve drawn to a standard wavelength scale, as aids in computation. The three sets of wavelengths have been derived from the color-mixture functions, adopted by the International Commission and shown in Fig. 1, and from the energy distribution of the light-source. These wavelengths are tabulated in the Handbook of Colorimetry,[1] which describes in detail the entire procedure of color measurement.

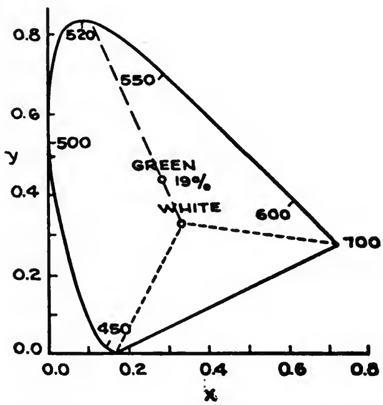

FIG. 3. Chromaticity diagram. Illuminant C (artificial daylight) has been used for the specifications of the white and green samples.

If the tristimulus values of one color are some fraction of the tristimulus values of a second color, then these colors will look alike, except that the first will be less bright. The brightnesses of all colors are measured by the second tristimulus value, Y, alone. The ratios,

$$x = X/(X+Y+Z), \quad y = Y/(X+Y+Z), \quad z = Z/(X+Y+Z)$$

are called *trichromatic coefficients*, and are the same for all colors that differ only in brightness. Such colors are said to have the same *chromaticity*, and the chromaticity can be represented by a point in the chromaticity diagram shown in Fig. 3. The value of z can always

be computed from the indicated values of x and y, since $x + y + z = 1$ for all colors. The chromaticities at the various wavelengths of the spectrum are represented by the points on the curve. The chromaticity of daylight is represented by the point near the center. The green sample used for illustration in Figs. 1 and 2 is represented by the point above the white point. The brightness, 19 per cent, of this sample relative to the brightness of a perfect white in the same illumination is written beside the point representing the chromaticity. The dominant wavelength, 526 mμ, analogous to the artist's hue, is the wavelength at which the straight line drawn through the white point and the sample point cuts the spectrum curve. The purity, 22 per cent, analogous to the artist's saturation, measures the distance from the white point to the sample point as a fraction of the distance from the white point to the dominant spectrum color.

Samples that should match in color should have the same tristimulus values. This condition can be satisfied without requiring that the energy distributions of the light reflected from the samples are identical. Samples that match in color will be represented at the same point in the chromaticity diagram and will have the same dominant wavelength and purity. Errors in color matching can be represented as distances in the chromaticity diagram, and can be analyzed into errors of dominant wavelength and of purity.

After the presentation of the paper, a 450-ft. 16-mm. Kodachrome motion picture was shown entitled "Color Measurement and Its Application to Color Photography." This film demonstrated the details and use of the method of color measurement described in the paper. A glimpse of the final steps in the preparation of a three-color subtractive print served as an introduction. A modified General Electric recording spectrophotometer was shown in operation, recording the spectrophotometric characteristics of the colors of a chart and of a subtractive reproduction of the chart. Close-up scenes emphasized important details of the double-prism monochromator, of the photometer mechanism, and of the modified integrating sphere and sample holders. The computation of tristimulus values, using the selected-ordinate method, was demonstrated in detail. In this demonstration, the speed and simplicity of the computations and of the recommended computing equipment were made evident. The interpretation of the colorimetric specifications was demonstrated, making use of the chromaticity diagrams published in the "Handbook of Colorimetry."[1] All the colors of the original color-chart and of the photographic reproduction were represented as points on a chromaticity diagram. The separations between points representing corresponding colors of the original and the reproduction were pointed out and compared with the visually apparent errors of the reproduction. This comparison led to the conclusion that the representation of the colors on the chromaticity diagram furnishes an adequate and unambiguous representation of all the visually important color errors.

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[1] Handbook of Colorimetry," *The Technology Press*, Cambridge, Mass. (1936).

DISCUSSION

MR. RICHARDSON: Do those errors represent the differences between the colors?

MR. MACADAM: The errors represented were the differences between the colors of the original color-chart and the corresponding colors of the reproduction. The colors used in the chart were picked as representative colors, likely to occur in any scene. The other ends of the error lines were simply the colors we found to have been produced by the color reproduction process. Perfect color reproduction would result in zero errors. Every color in the final color picture should fall on the same point in the diagram as the corresponding color of the original color chart.

MR. BAKER: In determining a color by dominant wavelength, purity, and brightness, has that method definitely ruled out the use of the trichromatic colorimeter?

MR. MACADAM: I think not. We use dominant wavelength, purity, and brightness because they give us quantities that are more meaningful. It does not avail one much to know that a color is 35 per cent green plus 10 per cent red plus 5 per cent blue; but if you tell him that a color has a dominant wavelength of 526 millimicrons, and if he is familiar with the appearance of the spectrum, he knows that the hue is a very definite type of green. If you tell him further that the color has a purity of 22 per cent, he knows that it is a relatively unsaturated green, as compared with the spectrum; and a brightness of 19 per cent indicates that it is a moderately dark green. Consequently, it is easy to interpret dominant wavelength, purity, and brightness. That does not mean we are going to carry out monochromatic colorimetry. We are going to use a spectrophotometer of some sort and compute the dominant wavelength, purity, and brightness as outlined in the paper. If we use any type of colorimeter we must use an observer who is in our employ, and we must not use very many observers; consequently, the values we get in visual colorimetry are subject to some uncertainty as to whether the observers are normal.

MR. KELLOGG: How do you specify dominant wavelength when the hue is purple?

MR. MACADAM: The dominant wavelength of a purple is nonexistent, and we specify the wavelength of the complementary color; for instance, the magenta has a complementary wavelength of about 520 millimicrons. That is the wavelength of the spectral color necessary to produce a neutral color in a color mixture with the magenta. If we extend a straight line from the point representing the magenta color through the white point, it will intersect the spectral curve at some wavelength, for instance, 520 millimicrons. That is the complementary wavelength.

MR. RICHARDSON: Suppose a colored film is to be shown to an audience; what would be the differences in reproduction with different light-sources; for example, low- and high-intensity arcs, Suprex, Mazda, and so on?

MR. MACADAM: Fortunately there would not be any large difference. The

color of the screen where we expect a white image seems to establish a standard by which we judge all the other colors. The film we have just shown was projected several weeks ago with a high-intensity carbon arc projector, and today with a high-efficiency tungsten lamp, and I can not notice any difference in the colors. It is interesting and fortunate that the relative quality of the colors does not seem to depend seriously upon the quality of the illuminant.

Mr. Hardy: Does not the difference in the reproduction correspond to observing a magazine illustration under daylight and under tungsten light? The difference in the quality of the light-source in that case is probably greater than what Mr. Richardson had in mind.

Mr. Kellogg: Since the sensitivity of the eye to brightness goes up so radically in the green as compared with the red and blue, why does not white light look green to us?

Mr. MacAdam: That is a question that must be answered by a rather philosophic argument: White is the appearance of the stimulus to which we are most accustomed, such as daylight. All other colors have hues with respect to this most familiar (*i. e.*, "colorless") stimulus.

Mr. Richardson: Theaters are now projecting much colored film, and I certainly feel that projectionists and exhibitors should be informed of the differences in color reproduction with the various kinds of light-sources in use.

Mr. MacAdam: I think it is rather generally expected that there will be differences. Whether they are important depends upon the observer, and I think we had better let the color-film people decide what light-source is best for the films resulting from each particular process.

Mr. Kellogg: Can we at least say that the complete spectrum must be pretty well represented to get satisfaction; in other words, that there must not be any bad "holes" in the spectrum?

Mr. MacAdam: I am afraid the questions are getting beyond the scope of my investigations.

Mr. Jones: I think under certain conditions, at least, one can see the difference between, let us say, high-intensity arc and tungsten projection of some colors. The adaptation of the eye, while it is great, is not under all conditions sufficient to compensate for this difference in light-source quality. Commercial organizations working on the development of color-films are studying the problem.

SOUND PICTURES IN AUDITORY PERSPECTIVE*

FRANKLIN L. HUNT**

Summary.—*Soon after sound reproduction in auditory perspective was demonstrated over telephone circuits between Philadelphia and Washington in 1933, experimental sound pictures in auditory perspective were made at the Bell Telephone Laboratories' sound picture laboratory. Listening tests showed that they distinctly enhanced the illusion that the sound originated at its apparent source on the screen and they strikingly improved the feeling of spaciousness and reality. The auditory perspective effect is not primarily dependent upon perfect synchronism of the two sound-tracks required, nor on frequencies above the present commercial range. Existing equipment can be converted to project sound pictures in auditory perspective without great difficulty.*

An auditor at the theater knows by his sense of hearing as well as by sight when an actor moves about the stage, and he can tell in what parts of an orchestra the various instruments are playing. Each of his ears hears sound from a slightly different direction, and he has learned by experience to associate the intensity and quality with the direction of origin of the sound. In a sound picture theater, on the contrary, the sound always comes from one fixed source, namely, the loud speakers behind the screen. This makes the reproduction resemble sound heard when an auditor listens directly to speech or music with only one ear. Under these conditions the perception of direction is seriously impaired.

It has been shown[1] that reproduced sound can be made to appear to move from one side of a stage to the other by connecting two or more independent sets of loud speakers by separate circuits to separate microphones. That this method gives startling effects was demonstrated in 1933 when symphonic music was transmitted by such means over telephone lines from Philadelphia and reproduced in Washington. In these experiments the sound was picked up by three microphones placed near the front of the stage at Philadelphia. Each microphone was connected by a separate telephone circuit to a

* Received June 4, 1938.

** Bell Telephone Laboratories, New York, N. Y.

separate set of loud speakers at Washington. With this arrangement the audience was able to locate sounds from different parts of the orchestra and there was a feeling of spaciousness which gave the reproduced music a remarkable sense of reality.

This perspective effect still persists if two microphones are used instead of three. In such case the middle microphone is omitted, and the remaining two are placed several feet apart in front of the orchestra. The output of each microphone is then amplified separately and applied to a separate set of loud speakers located behind a screen at positions corresponding to those occupied by the microphones on the stage where the sound originated.

The application of this multichannel method of reproduction to sound pictures requires in principle only the introduction, between the microphones and loud speakers, of recording machines to store the sound and reproducers to project it. Means for keeping the cameras and sound recorders in synchronism obviously have to be included. These facilities were available in the Bell Telephone Laboratories' sound picture laboratory and an investigation was presently begun into the possibilities of this multichannel method.

To study some of the effects that can be achieved, a series of experimental sound pictures was recorded in auditory perspective. Several scenes were made in a sound picture set built of reinforced plywood flats like those commonly used in commercial sound studios. In accord with the usual practice the set had three walls. It was open in front and above to provide easy access for the cameras and to permit lighting the scene. Two electrodynamic microphones were used to record the sound. They were located about ten feet apart at the front of the set in positions that were found by listening tests to cover the set most uniformly These listening tests were carried out, and the sound was monitored during recording, by diverting part of the output of each microphone to a separate loud speaker located in the monitoring room associated with the stage. The output of each microphone was connected by a separate channel to a standard film-recording machine. The two recording machines and the camera that photographed the action were synchronized by a standard Western Electric interlock system.[2] The sound records and the picture were originally recorded on separate films but afterward the picture and one sound-track were printed on one film in accordance with standard practice. The second sound-track was printed on another film.

The sound picture scenes recorded were selected primarily to de-

termine how faithfully the sound appeared to localize itself at its apparent source on the screen, and included the following scenes:

(*1*) A person walking about the set from side to side, front to back, and forward again, speaking as he walked.
(*2*) A banjo player walking about the stage while playing.
(*3*) A banjo and saxophone, played alternately on opposite sides of the stage.
(*4*) A piano played on one side of the stage.

To reproduce the records two standard sound picture projectors were used, coupled by a flexible shaft to keep them in synchronism. The combined picture and sound-track were projected by one machine and the second sound-track by the other. The output from each sound-track was amplified by a separate amplifier and supplied to a separate loud speaker. Western Electric cone speakers were used for most of the tests but in some cases high-frequency units were added. It was found, however, that the latter were not necessary to produce the auditory perspective effect. The loud speakers were located behind the screen near the right- and left-hand edges, and about half-way up from the bottom of the screen. Tests were also made with the loud speakers just outside of the screen and again about five feet away at each side. Neither of these positions gave as satisfactory an illusion as when the speakers were behind the screen, although the difference was not great when they were just outside. In some of the experiments low-pass filters, cutting off frequencies above 7000 cps., were connected in the loud speaker circuits to determine whether the auditory perspective effect depended upon the presence of frequencies above the 7000-cps. limit. It persists without them.

The recordings were reproduced before several groups of observers, who, in a blind test, were asked to distinguish between the auditory perspective records and one or more of the following conditions:

(*1*) The output of one of the two auditory perspective sound-tracks applied to a single loud speaker in the usual location.
(*2*) The output of the two sound-tracks combined electrically and projected through a single loud speaker located behind the screen at the center.
(*3*) The output of one sound-track applied simultaneously to the two loud speakers—one at each side of the screen.
(*4*) The output of the two sound-tracks combined electrically and projected from the two loud speakers.

The tests were made by switching back and forth quickly between the conditions mentioned above and requiring the observers to de-

cide which condition prevailed at the moment. In most of the tests two conditions were compared at a time, but in some instances there were three. An audible signal was used to indicate that a change was about to be made because the action on the screen continued without interruption. To assure an unbiased decision, however, the change signal was sometimes given without changing the sound circuit.

Comparisons were made also between the auditory perspective recording of the first scene and one recorded by present commercial methods with a single microphone located at the center of the stage. Quick shifts from one condition to the other could not be arranged for

TABLE I

Test	Observers	Circuit Combinations	Number of Observations	Per Cent Observations Correct	Kind of Record
1	*A*	*2T-2S vs. 1T-1S*	15	100	Piano
2	*A*	*2T-2S vs. 1T-2S*	16	81	Speech-walking
			13	100	Banjo-walking
			4	100	Saxophone and banjo
			23	96	Piano
3	*B*	*2T-2S vs. 1T-1S*	16	100	Piano
4	*B*	*2T-2S vs. 1T-2S*	20	100	Speech-walking
			8	50	Banjo-walking
			17	82	Saxophone and banjo
			14	93	Piano

this part of the test because equipment was not available to project two pictures and three sound-tracks simultaneously; nevertheless, the auditory perspective recordings were preferred by all who heard the comparison.

Experimental Results.—The results are summarized in Tables I and II, where a letter is used to designate each of the seven observers. The circuit combinations are indicated by the number of sound-tracks (T) and loud speakers (S) used. For example, *2T-2S* is the auditory perspective condition. *2T comb.-2S* means two sound-tracks combined electrically and applied to two loud speakers. The first table gives the per cent of correct observations and the second the per cent of correct choices for each circuit combination as they were played in succession. In tests *1* to *4*, *7* and *8*, the observers were told which combination was to be tested and were asked to indicate which one

prevailed each time after the signal for the change was given. In tests *5* and *6*, the three combinations used in each test were assigned numbers and then played successively at random. At each change the operator announced the number of the combination being switched in at that time, and after the test each observer indicated the combination that he thought corresponded to the given number.

TABLE II

Test	Observers	Circuit Combinations	Numbers of Observations	Per Cent of Correct Observations for Each Circuit Combination	Kind of Record
5	*CDEF*	*2T-2S*	12	100	Paino
		1T-2S	12	75	Piano
		1T-1S	12	75	Piano
6	*CDEF*	*2T-2S*	12	75	Speech-walking
		1T-2S	12	50	Banjo-walking
		1T-1S	12	75	Saxophone and banjo
7	*DEFG*	*2T-2S*	44	73	Piano
		2T comb.-2S	44	62	Piano
		2T comb.-1S	36	69	Piano
8	*DEFG*	*2T-2S*	78	64	Speech-walking
		2T comb.-2S	92	53	Banjo-walking
		2T comb.-1S	77	75	Saxophone and banjo

The tables show that the ability to distinguish between the auditory perspective condition (*2T-2S*) and either single loud-speaker reproduction from one sound-track (*1T-1S*) or single sound-track reproduction from two loud speakers (*1T-2S*) is of high order. When three conditions are imposed, as in the last four series, the number of errors is larger but still small enough to indicate that the effects are real and can not be explained as selection by chance.

To show the effect of imperfect synchronization of the films the experiment of displacing one sound-track relative to the other was tried. As the displacement increased, an increase in the apparent reverberation of the sound occurred. This became obvious with a displacement of between one and two frames. When increased to four frames the effect was very obvious, and when the difference became eight frames the time lag was sufficient to give a distinct echo.

Synchronism was maintained within a quarter of a frame, that is, within one sprocket hole, when the sound-tracks were printed.

It was agreed by those who heard these auditory-perspective sound pictures that they distinctly enhanced the illusion that the sound originated from the source shown on the screen and that the sound appeared to follow the image of the source as it moved. There was striking improvement in the feeling of spaciousness and reality, that is, the feeling that the sound originated in an actual room of three dimensions. In previous auditory-perspective demonstrations frequencies up to 15,000 cps. have been reproduced, but these experiments show that the effects still persist strongly when combined with motion pictures if frequencies up to only 7000 cps. are used.

Since these experiments were carried out the art has been advanced by others. A public demonstration of sound pictures incorporating these ideas in practical form was given by Electrical Research Products, Inc., at Bell Telephone Laboratories in 1937.[3] In these tests two sound-tracks were recorded simultaneously on a single film in the space ordinarily occupied by one sound-track. For this purpose a light-valve with two pairs of ribbons was used. One pair was actuated by current from the channel at the right side of the stage and the other by the channel at the left. To reproduce the records the outputs of the two sound-tracks were picked up by a double photoelectric cell, each unit of which was connected to a separate amplifying system and to separate loud speakers. Each loud speaker comprised two units: a cone with a box baffle to radiate the low frequencies, and a multicellular horn for frequencies above 300 cps. The range radiated was from 50 to 8000 cps.

The pictures shown included that of a large orchestra, which gave the audience an opportunity to observe that the sounds from the various instruments emanated from the positions where the instruments appeared in the picture. In another scene the sound of a ping-pong ball striking the bat or table passed from side to side as the ball was struck back and forth. A third scene started with an unlighted screen from which noise and voices came as the actors apparently stumbled about in the dark. Later a third actor arrived. As he turned on the lights, the picture of a somewhat disordered living room appeared upon the screen. This gave the audience an opportunity to compare the apparent origins of the sounds occurring at the moment with the actors' actual positions in the picture.

These demonstrations and those previously described show that sound pictures in auditory perspective can be added to present-day sound picture equipment without great difficulty and that they distinctly enhance the realism of the presentation. The practical application of the method gives promise of being another significant step in perfecting the new art that has played so large a part in revolutionizing popular entertaiment during recent years.

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APPLICATION OF ELECTRICAL NETWORKS TO SOUND RECORDING AND REPRODUCING *

H. R. KIMBALL**

Summary.—*The use of electrical networks with recording and reproducing systems to accomplish beneficial results has been steadily increasing. Two types of networks are in general use, namely, wave-filters and attenuation equalizers. This paper discusses in some detail the use of these networks with sound systems as reflected by present practices and later presents practical data for engineering the networks with a minimum of time and effort. The uses to which attenuation equalizers are put divide these networks into two general classes: first, fixed equalizers to provide fixed equalization for sound channels; and, second, variable equalizers to provide means for varying at will the relative amplitudes of the frequency components of sound signals. Although the means for engineering variable networks is far from being ideal, the review given in the paper of present practices should be valuable.*

Electrical networks such as wave-filters, attenuation equalizers, transformers, *etc.*, are devices used as links in transmission systems for altering in some specified manner the transmitted electrical signals. Networks of this sort have been important parts of signal-transmission systems for some time. In the communication field, for instance, many of the facilities in daily use would be impossible without such networks. In fact, realization of the commerical applications of networks by the communication industry is mainly responsible for the great amount of effort put forth to perfect the devices.

At the time sound with motion pictures became commercially practicable, the development of networks had reached an advanced stage, making them directly available for use in the new industry. But new fields of endeavor require new methods of design and application. Such has been the experience in sound pictures. The technic of using networks with sound recording systems differs from that of using them with communication systems. Progress has been made toward applying networks to sound picture purposes but much yet remains to be done. This paper outlines some of the applications of

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** Metro-Goldwyn-Mayer Pictures, Culver City, Calif.

networks to sound picture work and gives some useful data especially arranged to meet the needs of studio sound departments.

Sound originates from its source in the form of pressure variations in the air. The microphone, when properly placed, converts these acoustic variations into corresponding electrical variations which, when amplified, may be recorded on film. The simplest form of sound is a pressure wave varying sinusoidally with time. Complex waves, such as speech, music, *etc.*, consist of large numbers of these simple components variously arranged with respect to amplitude, phase, time spacing, and time duration. The frequencies involved may range anywhere between twenty cycles per second and twenty thousand cycles per second. For speech and music these components consist of constantly shifting fundamental frequencies and their harmonics. Sound, then, is identified by the frequency components contained in the pressure wave. Any change made in the components changes the character of the sound as identified by the ear in the same manner as if the signal were emitted in the changed form initially.

Electrical networks when arranged for use with sound systems are provided with a pair of input terminals for connecting to a system to receive energy, and a pair of output terminals to permit delivery of the modified signal back to the system. A signal in traversing the system from the input terminals to the output terminals can be modified by the network in only a few ways. For instance, (*1*) the signal can be delayed in time by means of delay networks, (*2*) the relative phase relation of its frequency components can be altered by networks known as phase correctors, (*3*) the signal can be decreased in volume with the use of attenuators, (*4*) the band of frequencies freely transmitted can be restricted to some definite limits by means of wave-filters, and (*5*) the relative amplitudes of its frequency components can be altered to effect a change in quality by means of networks known as attenuation equalizers. Ordinarily the first two of these items are not of value in sound-picture work—the first for the reason that time-delay by means of networks is too costly for the benefits received, and the second because phase correction of the type easily obtained with networks is not usually needed in sound work. The other networks, attenuators, attenuation equalizers, and wave-filters are used quite freely.

As already mentioned, an attenuation equalizer is a network whose attenuation loss, over a given frequency range, varies with frequency in some desirable manner. This means that if a number of

frequencies of given amplitudes are simultaneously impressed upon the input terminals of an equalizer, the relative amplitudes of these frequencies will be changed when delivered to a load connected to the output terminals. The manner in which this change takes place is determined and can be controlled by the design of the equalizer. In sound picture work, the frequency range required extends from about 40 or 50 to 7500 or 8000 cycles per second. This is called the transmission band. Equalizers for sound work then, are usually arranged to render a specified transmission characteristic in this range and little attention is given to what they do outside the range.

Wave-filters provide the means for defining the recorded band; that is, they freely pass the above-mentioned frequency range and considerably attenuate other frequencies. The filters used in sound recording and reproducing channels are either of the low-pass or the high-pass type, there being little need for band-pass designs.

Two general types of such networks are used in sound systems; that is, fixed networks and variable networks. By a fixed network is meant one whose transmission characteristic can not readily be changed; while a variable network is one provided with controls for varying its characteristic over a prescribed range. Fixed networks are usually used with recording and reproducing equipment to compensate for any unavoidable distortions occurring, for various reasons, in the equipments, and to provide the fixed transmission characteristics that have been found to produce the best average product with the recording and reproducing equipments available. These characteristics for the different parts of a system may or may not be linear, depending upon the equipment limitations. Variable type networks or "patch-in" networks are usually concentrated almost exclusively at the re-recording mixer positions, where the sound quality for the complete picture can be made uniform and sound effects rehearsed and altered as desired to obtain the best overall results.

Recording Networks and Complementary Recording.—The networks used in the original recording of sound are few in number and simple in construction. They often consist of a high-pass filter of one or two sections having a cut-off at about 60 cps., and a low-pass filter with a cut-off at about 7500 cps. These define the recording band from the frequency standpoint. The high-pass filter is to remove excessive stage boominess in a low-frequency range that is otherwise not important. The low-pass filter removes unimportant frequencies

in the upper part of the frequency range. In the case of variable-density recording, this is an important function as it prevents overloading and perhaps breakage of the light-valve in the vicinity of valve resonance.

Recently a method of recording known as complementary* recording was put into effect at one major studio, requiring the use of one equalizer in the recording circuit to pre-equalize the recorded material, and another in the reproducing circuit to post-equalize this circuit in a complementary manner. Fig. 1 shows the recording characteristic obtained with the pre-equalizer and

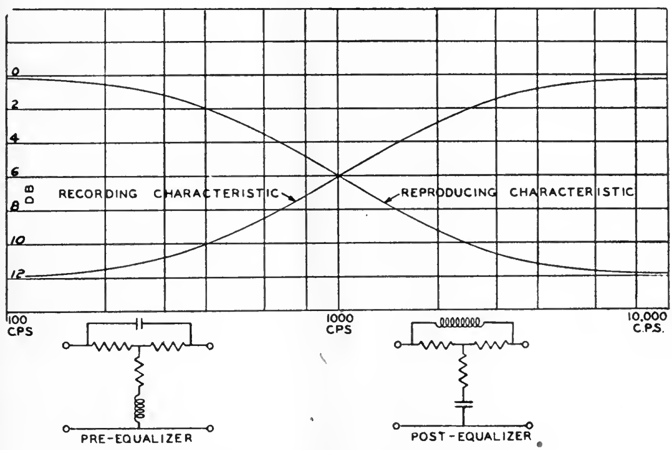


FIG. 1. Complementary recording.

the reproducing characteristic derived from the post-evualizer. When these two equalizers are used in this manner, the overall amplitude-frequency characteristic is unchanged because of the complementary nature of the equalizers, the amplitude distortion introduced by the pre-equalizer being compensated for by the post-equalizer. Referring to Fig. 1, it will be noted that the pre-equalizer has an insertion loss of about 12 db. at 100 cps., 6 db. at 1000 cps., and

* Because of the necessity of employing a post-equalizer in the reproducing system, complementary recording can not as yet be used for release prints. It is the hope that joint action to provide post-equalizers for all theater equipment will soon be possible.

very little loss at the high frequencies. In general, most of the transition from 12 db. loss to 0 db. loss occurs in the frequency range from 300 to 3000 cps. The half-loss frequency of 1000 cps. is one of the design parameters of the equalizers.

It is well known that a large part of the energy content of sound signals lies in the low-frequency range, say from 200 to 500 cps. Insertion of the above-described pre-equalizer into a normal recording channel without any change in the channel gain removes a large part of the signal load from the recording mechanism and the film, leaving the high-frequency content at approximately the same level. Because of the removal of the low-frequency load, it is possible to increase the recording channel gain, thus increasing the recorded level of the high-frequency content and achieving a greater ratio of high-frequency signal to static surface noise; that is, an increase in noise-reduction. Subsequent post-equalization does not destroy this increased noise-reduction because of the concentration of surface noise in the upper part of the frequency spectrum.

Complementary recording also effectively eliminates "breathing," by which is meant the audible change in surface noise caused by the recording mechanism's being placed, by the noise reduction equipment, in the proper position to handle the signal. For normal recording the greater the signal volume the greater is the breathing, and since most of the signal energy lies in the low-frequency range, much of the breathing is produced by the lower-frequency components of the signals. It may be mentioned also that masking is a factor in breathing because when breathing is produced by a high-frequency signal, the surface noise is masked somewhat by the signal. Use of this type of pre-equalizer in the recording circuit therefore considerably reduces breathing because the recording mechanism is not modulated nearly as much by the low-frequency signal content.

Complementary recording has also a few other associated benefits. For instance, intermodulation, causing spurious signal products, is reduced because of the lower level of the low-frequency components. Bias current components also are reduced for the same reason. In addition, wave-top clipping on steep wave-fronts, caused by the sluggishness of the noise-reduction equipments, is reduced. Still again, complementary recording provides greater margin of operation for the low-frequency components thus permitting occasional high-peaked signals to be handled with less overload. This is equivalent to an increase in volume range.

In conclusion, it may be mentioned that complementary recording accomplishes beneficial results for two basic reasons; first, the energy distribution of acoustic signals lies in the lower part of the audible frequency spectrum, and, second, film surface noise is concentrated in the upper part of the frequency range. Reducing the level of the recorded signals in the low-frequency range does not materially increase the signal-to-static surface-noise ratio in this same range, but,

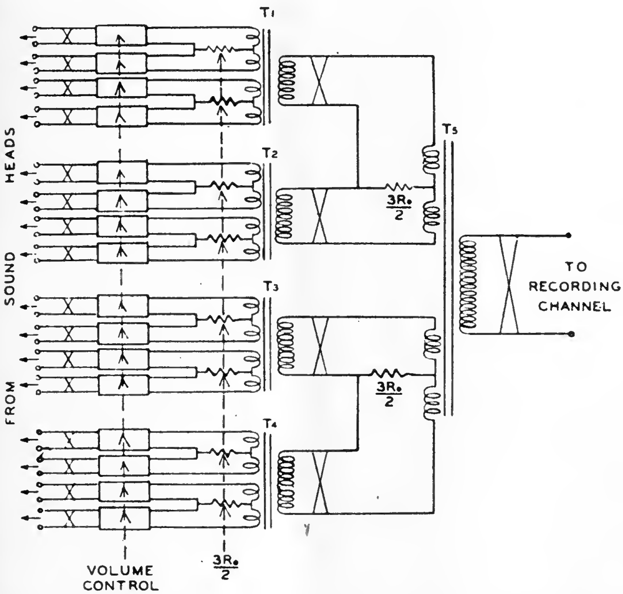


FIG. 2. Mixer circuit; 12-db. insertion loss (x = constant-resistance patching points.

on the contrary, permits the over-riding of surface noise in the upper frequency range. This, in connection with the reduction in breathing, decreased intermodulation effects, and the other items outlined above constitute the benefits of this method of recording.

Re-recording Arrangements.—Re-recording rooms are usually arranged to have acoustic characteristics approximating those of average large motion picture theaters. This is necessary in order that the re-recording mixers may adjust the sound quality and effects to produce the results desired when the record is reproduced in an average theater. Facilities are made available to permit joining

the sounds from a number of sound-tracks, by means of a mixir table, to form one composite signal for monitoring and for re-recor ing. Combining as many as eight tracks into one is not unusual, ar sometimes as many as twelve sound-tracks are joined. The mixir table is arranged so that each track may be dealt with separately a number of tracks as a unit.

Fig. 2 shows a mixing table arrangement permitting joining maximum of sixteen sound-tracks into one. Patching points a available for the insertion of networks into the circuit of each soun track or at points where the sound-tracks are combined in groups four. At each point where networks may be inserted, the circu impedances are equal resistances in the two directions, so that ar inserted network will operate between its designed resistance Where constant-resistance networks are inserted, this permits tl operation of any number in tandem without altering the characteri tics of the individual networks. This constant-resistance featu at the patching points is made possible by the design of the mix coil, which may be designed to combine any number of circuits multiples of two into one channel. For instance, the sixteen-positic mixer of Fig. 2 could be handled by means of only one mixer co For flexibility of patching, however, the four-position coil seen more practicable. The insertion loss through the mixing circuit Fig. 2 is 12 db., or 10 log 16. This is the minimum loss that can l obtained for the sixteen positions.

The above-described mixing circuit is only one of a number of a rangements that can be used. Usually it is not necessary to provic as many as sixteen mixer positions. Some saving in equipment ca be achieved where a smaller number of mixer positions is satisfactor The general requirements are to provide minimum insertion los flexibility of patching, and constant resistance at the patching point

A large variety of fixed and variable-type equalizers and filte are available for re-recording. There are at the present time no stan ard networks in use by all the studios although many of the studi have quite similar equipments.

Reproducing Networks.—As in recording systems, the networl required in reproducing sound are few in number and simple in desig Most reproducing systems employ only two networks: one a lov pass filter to suppress system and surface noise lying above the us ful signal frequencies, and the other a dividing network for use wit the loud speaker system. The low-pass filter is often of the variab

ype, permitting adjustment of its cut-off to suit the theater in which : is installed. Information is given later in this paper regarding the arious types of dividing networks. In addition to these types of etworks some reproducing systems employ equalizers for compenating for loud speaker characteristics, but these are of special design nd will not be discussed here.

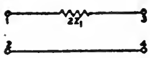
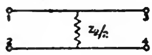
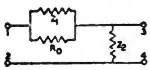
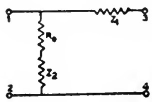
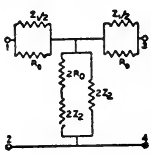
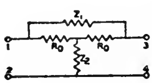
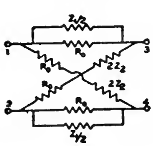
Miscellaneous Networks.—In addition to the above-mentioned networks, which are more or less standard, a number of different types f networks are used in various test equipments, and for special urposes such as for equalizing microphones of different types, for ompensating for room effects, *etc.* These are usually of conventional design and present no great difficulties.*

Attenuation Equalizers.—As already mentioned, an attenuation qualizer is a four-terminal network whose attenuation loss, over a iven frequency range, varies with frequency in some desirable ıanner. This means that if a number of frequencies of given amlitudes are simultaneously impressed upon the input terminals of n equalizer, the relative amplitudes of these frequencies will be hanged when delivered to a load connected to the output terminals. 'he manner in which the change takes place is determined and can e controlled by the design of the equalizer. In practice the shapes equired of the insertion-loss curves of equalizers appear to vary over wide range. Actually, many equalizer problems are but duplicaions of others with different values assigned to the network contants.

From the great amount of work that has been done on the design f attenuation equalizers a number of general circuit arrangements ave emerged that have proved to be the most satisfactory for general se. The network engineer does not necessarily restrict himself to he use of these few types but they do represent a large part of his it of tools. These equalizer circuits are designated in the following nanner:

1) Series impedance type.
2) Shunt impedance type.
3) Full series type.
4) Full shunt type.
5) *T* type.
6) Bridged-*T* type.
7) Lattice type.

* Some of the information from this point on is summarized from data in 'Motion Picture Sound Engineering." (*Cf.* ref. 1, p. 380.)

Network	*Type*	Z_{12}	Z_{34}	*Insertion Loss*
	Series Imp.	Not Constant	Not Constant	$20 \log \frac{R_0 +}{R_0}$
	Shunt Imp.	Not Constant	Not Constant	$20 \log \frac{R_0 +}{Z_2}$
	Full Series	R_0	Not Constant	$20 \log \frac{R_0 +}{R_0}$
	Full Shunt	R_0	Not Constant	$20 \log \frac{R_0 +}{R_0}$
	*T*	R_0	R_0	$20 \log \frac{R_0 +}{R_0}$
	Bridged *T*	R_0	R_0	$20 \log \frac{R_0 +}{R_0}$
	Lattice	R_0	R_0	$20 \log \frac{R_0 +}{R_0}$

NOTES:

(1) $Z_1 Z_2 = R_0^2$ for all networks

(2) $20 \log \frac{R_0 + Z_1}{R_0} = 20 \log \frac{R_0 + Z_2}{Z_2}$

(3) Working Circuit =

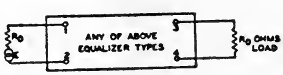


FIG. 3. Fundamental equalizer types.

Fig. 3 shows these seven equalizer types in schematic form. For these circuits, it is assumed that the system impedances to which connection is made for operation are equal resistances of R_0 ohms. In sound picture work R_0 has values of the order of 500 ohms, 200 ohms, 16 ohms, and various other resistances. The variable characteristics of the equalizers are made to depend upon two general impedances denoted in the circuits as Z_1 and Z_2 and defined as being inverse to each other with respect to the line resistance R_0; that is,

$$Z_1Z_2 = R_0^2$$

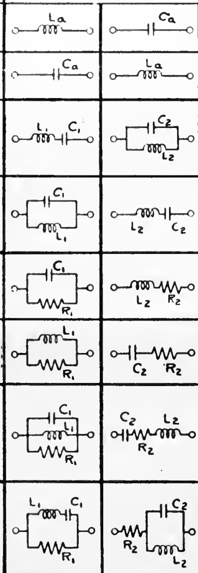
It is noted that the insertion-loss formula, as expressed by the equation

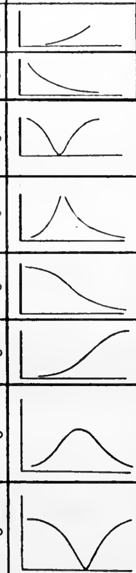
$$I.L. = 20 \log \frac{R_0 + Z_1}{R_0} = 20 \log \frac{R_0 + Z_2}{Z_2}$$

is applicable to each of the equalizer types. This means that an insertion-loss characteristic obtained with one of the equalizer types can be duplicated by any of the other types. The formula shows also that the shapes of the insertion loss curves of the equalizers of Fig. 3 are determined solely by the inverse arms of the networks as represented by impedances Z_1 and Z_2. This feature makes it practicable, in a design problem, to determine the circuits of the inverse arms independently of the equalizer types with which they are to be used.

Since the same insertion loss characteristic may be obtained with any of the equalizers of Fig. 3, the question naturally arises as to the advantages of one type over another. In this connection it will be noted from the figure that the input and output impedances for the types are not the same. For the first two types, both these impedances vary with frequency; for the next two types one impedance is constant and the other one varies; and for the last three types, both Z_{12} and Z_{34} are constant. Then, for instance, where a constant-impedance network is needed, one of the last three types must be used. Commercial features also help in making this decision, as one would select the type easiest to build which meets the circuit requirements.

The impedances Z_1 and Z_2 may take any form of circuit arrangement so long as they are inverse to each other. In practical work a few common circuit arrangements are sufficient for most purposes. Fig. 4 shows eight pairs of simple inverse circuits for which data





Pairs	Inverse Arms Z_1	Inverse Arms Z_2	Insertion Loss Characteristic	Insertion Loss Formulas	L_1	C_1	L_2	C_2
1	L_a	C_a		$10 \text{ Log} \left(\frac{f}{f_a}\right)^2$	$L_a = \frac{R_o}{2\pi f_a}$			$C_a = \frac{1}{2\pi f_a R_o}$
2	C_a	L_a		$10 \text{ Log} \left(\frac{f_a}{f}\right)^2$		$C_a = \frac{1}{2\pi f_a R_o}$	$L_a = \frac{R_o}{2\pi f_a}$	
3	L_1, C_1	C_2, L_2		$10 \text{ Log} \left[1 + \frac{\left(\frac{f}{f_R} - \frac{f_R}{f}\right)^2}{\left(a - \frac{1}{a}\right)^2}\right]$	$L_a \frac{1}{a^2 - 1}$	$C_a \frac{a^2 - 1}{a^2}$	$L_a \frac{a^2 - 1}{a^2}$	$C_a \frac{1}{a^2 - 1}$
4	C_1, L_1	L_2, C_2		$10 \text{ Log} \left[1 + \frac{\left(a - \frac{1}{a}\right)^2}{\left(\frac{f}{f_R} - \frac{f_R}{f}\right)^2}\right]$	$L_a \frac{a^2 - 1}{a^2}$	$C_a \frac{1}{a^2 - 1}$	$L_a \frac{1}{a^2 - 1}$	$C_a \frac{a^2 - 1}{a^2}$
5	C_1, R_1	L_2, R_2		$10 \text{ Log} \left[1 + \frac{K^2 - 1}{1 + K\left(\frac{f}{f_b}\right)^2}\right]$		$C_b \frac{\sqrt{K}}{K - 1}$	$L_b \frac{\sqrt{K}}{K - 1}$	
6	L_1, R_1	C_2, R_2		$10 \text{ Log} \left[1 + \frac{K^2 - 1}{1 + K\left(\frac{f_b}{f}\right)^2}\right]$	$L_b \frac{K - 1}{\sqrt{K}}$			$C_b \frac{K - 1}{\sqrt{K}}$
7	C_1, L_1, R_1	C_2, L_2, R_2		$10 \text{ Log} \left[1 + \frac{K^2 - 1}{1 + \frac{\left(\frac{f}{f_R} - \frac{f_R}{f}\right)^2}{\left(b - \frac{1}{b}\right)^2}}\right]$	$L_b \frac{K - 1}{\sqrt{K}} \frac{b^2 - 1}{b^2}$	$C_b \frac{\sqrt{K}}{K - 1} \frac{1}{b^2 - 1}$	$L_b \frac{\sqrt{K}}{K - 1} \frac{1}{b^2 - 1}$	$C_b \frac{K - 1}{\sqrt{K}} \frac{b^2 - 1}{b^2}$
8	L_1, C_1, R_1	R_2, C_2, L_2		$10 \text{ Log} \left[1 + \frac{K^2 - 1}{1 + \frac{\left(b - \frac{1}{b}\right)^2}{\left(\frac{f}{f_R} - \frac{f_R}{f}\right)^2}}\right]$	$L_b \frac{K - 1}{\sqrt{K}} \frac{1}{b^2 - 1}$	$C_b \frac{\sqrt{K}}{K - 1} \frac{b^2 - 1}{b^2}$	$L_b \frac{\sqrt{K}}{K - 1} \frac{b^2 - 1}{b^2}$	$C_b \frac{K - 1}{\sqrt{K}} \frac{1}{b^2 - 1}$

f_R = Resonance and anti-resonance frequency of inverse arms.
f_a = Frequency of 3-db. insertion loss.
f_b = Frequency of half loss.
Maximum loss = 20 log K
R_o = Circuit impedance.

$a = f_R/f_a$ $b = f_R/f_b$
$L_a = R_o/2\pi f_a$ $L_b = R_o/2\pi f_b$
$C_a = 1/2\pi f_a R_o$ $C_b = 1/2\pi f_b R_o$

FIG. 4 Equalizer design data.

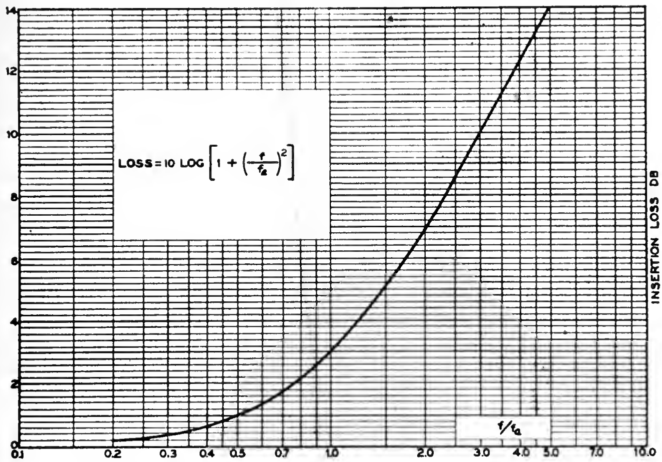


FIG. 5. Insertion loss—No. 1 inverse arms.

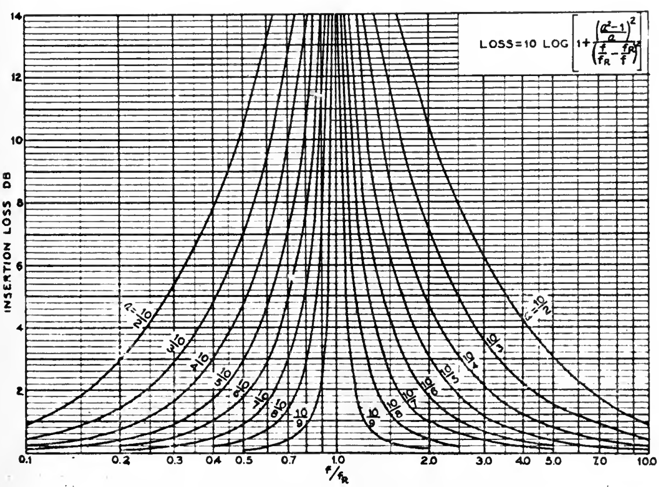


FIG. 6. Insertion loss—No. 4 inverse arms.

are given in this paper. Each of these pairs may be used with any of the equalizers of Fig. 3, provided the modifications shown for the various types in Fig. 3 are made; that is, $2Z_1$, $Z_1/2$, $Z_2/2$, $2Z_2$ *etc.*

The insertion-loss formula for each pair of inverse arms and the general form of the insertion loss characteristic are also given (Fig. 4). It will be noted that the insertion-loss curves for the first four pairs of arms range from zero to infinity. This is because these inverse arms are purely reactive, and their impedances vary between zero and infinity. For these four pairs of inverse arms the frequency f_a is defined as the frequency where a 3-db. insertion loss is obtained. This frequency f_a is a design parameter. The symbol f_r is used to designate the resonance or anti-resonance frequencies of the arms, where of course, such points exist. Because of the inverse relation between Z_1 and Z_2, the resonance frequency of one is the anti-resonance frequency of the other. The symbol a is used to denote the ratio of f_r to f_a, that is, $a = f_r/f_a$. In cases where f_a might be either greater or less than f, the lower frequency is selected for f_a so as to make the value of a always greater than unity.

The networks obtained by the use of the last four pairs of inverse arms have no infinite insertion-loss points, but vary between zero and some finite value determined by the symbol k. That is, the maximum insertion loss is 20 log k, and therefore k is a design parameter that becomes known when the maximum loss desired for a network is known. The symbol f_b is used to indicate the frequency where one-half the maximum loss is secured or 10 log k. The symbol b denotes the ratio f_r/f_b, and again f_b is always selected to be less than f_r so that b is always greater than unity.

The values assigned to k, f_r, f_a, and f_b determine the electrical elements for the inverse arms. Having decided upon a particular pair of these arms, they may be used with any of the equalizer types of Fig. 3. The formulas for computing the elements from a knowledge of R_0, k, f_r, f_a, and f_b are given in Fig. 4.

For design work it is useful to have curves available to aid in selecting the fundamental design parameters. These have been prepared to cover a wide range of applications. Figs. 5, 6, 7, 8, and 9 are examples of such curves. The recent book[1] on sound engineering contains a complete set of design charts and tables as well as material showing the preparation and use of the formulas. These data are too voluminous to be given here.

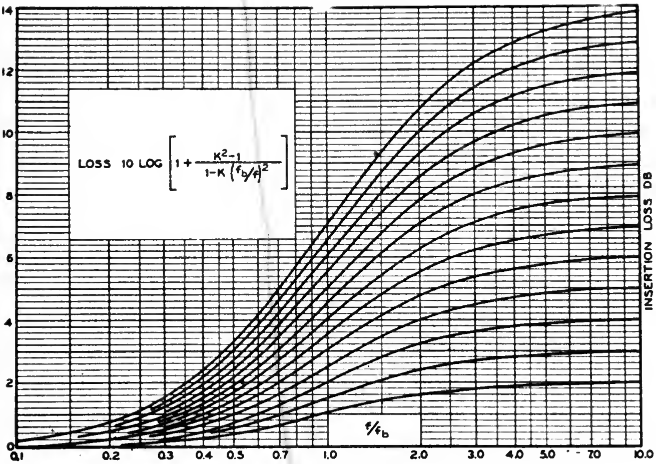


FIG. 7. Insertion loss—No. 7 inverse arms.

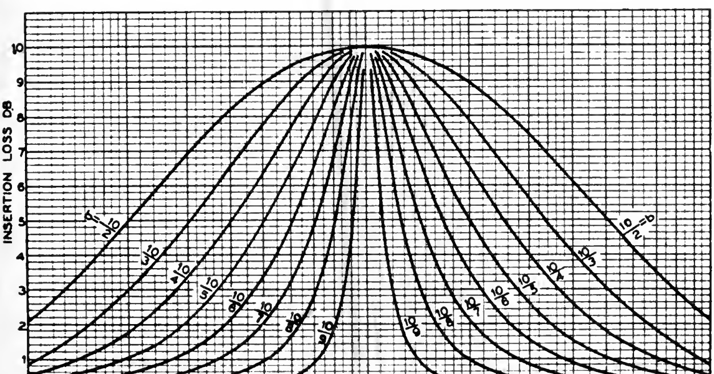


FIG. 8. Insertion loss—No. 7 inverse arms.

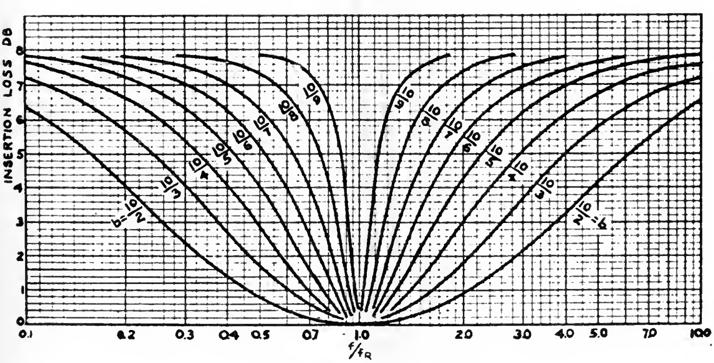


FIG. 9. Insertion loss—No. 8 inverse arms.

Wave-Filters.—Electric wave-filters, like attenuation equalizers, are four-terminal networks having a pair of input terminals and a pair of output terminals. Between the input and output terminals is an orderly array of electrical elements arranged so as to produce a specified insertion-loss characteristic when connected between the proper terminal impedances. Unlike equalizers, resistive elements are excluded from wave-filters; only inductive and capacitive elements being used to interconnect the input and output terminals. The reason for the exclusion of resistive conductors is contained in the purpose of a filter; *i. e.*, to transmit, without appreciable loss, all frequencies of the transmission band, and to attenuate by a prescribed amount frequencies lying outside this band. If resistive elements were used attenuation would result within the transmission band.

Electric wave-filters consist usually of a number of filter sections of unit four-terminal networks connected in tandem on a matched-impedance basis to form the complete filter. It is not necessary that a filter consist of more than one section, but usually the transmission characteristic desired is such as to require the use of multiple sections. In this respect filters are different from equalizers, where in a great many cases, the desired equalization curves may be secured without tandem operation of sections.

Conventionally designed wave-filters seldom provide constant impedances at their terminals over the operating frequency range, and for that reason it is usually not possible to achieve a match of impedance between the wave-filter and the system to which it is connected, even though the impedances of the latter are constant resistances. In general, the terminal impedances of filters are largely resistive in their transmission bands and reactive in the attenuation ranges. In addition, in the transmission range the resistive characteristics vary with frequency, especially in the cut-off region. While various methods are available of stabilizing these impedances to almost any desired precision, most filters, as arranged for commercial purposes, provide some mis-match at their terminals. The insertion loss of a filter takes into account these terminal effects and for that reason it is important in operating filters to make sure that the proper connecting impedance conditions are obtained.

Although wave-filters transmit the frequencies of their transmission band without appreciable attenuation loss, they do shift the relative phases of all the frequencies. This is an inherent feature

of filters that can not be avoided, although in some cases means are available for controlling the phase-shift characteristic so as to minimize its effect upon transmission. In many transmission systems, the effect of phase-shift is not of sufficient magnitude to require correction, while in certain types of systems corrective means must be employed. In sound pictures it has not been found necessary to correct for the phase-shift in the filters generally used.

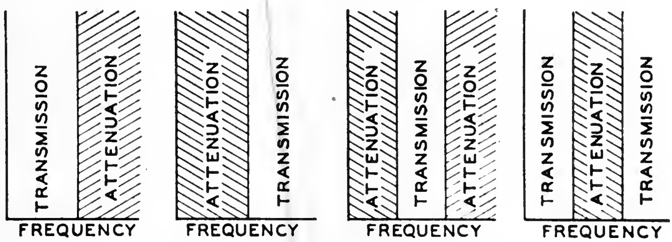


FIG. 10. Filter transmission bands.

For design and nomenclature purposes, wave-filters are classified into four types, in accordance with their attenuation characteristics:

(*1*) Low-pass filters.
(*2*) High-pass filters.
(*3*) Band-pass filters.
(*4*) Band-elimination filters.

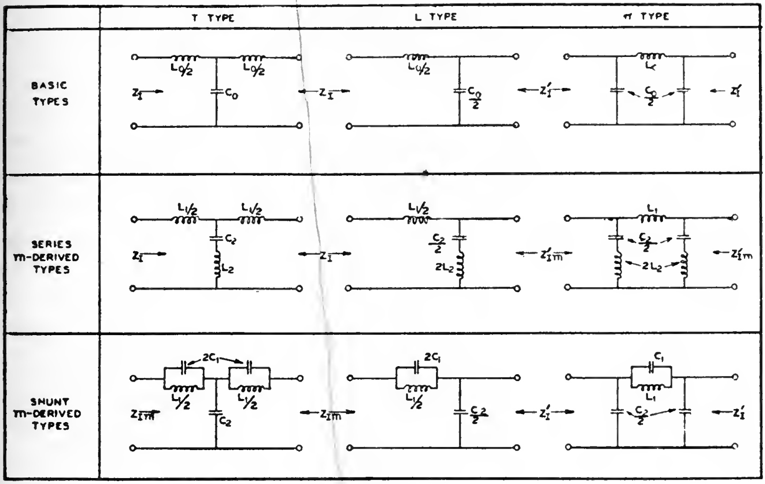
For low-pass filters, the passing band includes the frequency range from zero frequency to some finite frequency. For high-pass filters the passing band covers the range from infinite frequency down to some finite frequency. A band-pass filter transmits a definite band of frequencies, and attenuates frequencies lying outside the band. A band-elimination filter transmits all frequencies except a band of frequencies to be attenuated. Band-elimination filters, although forming an integral part of classified filter theory, are seldom used, for the reason that there is very little commercial need for filters having that type of attenuation characteristic. Fig. 10 shows the transmission and suppression ranges for the different types of filters.

Figs. 11 and 12 show the low-pass and high-pass filter sections most commonly used in practice. Filters consisting of tandem sections are obtained by joining together the various sections shown on a matched image-impedance basis. The terminals of the sections having like image impedances are indicated in Figs. 11 and 12.[2]

Dividing Networks.—In the design of linear sound reproducing equipments where it is desired to reproduce faithfully tones from about 50 cycles per second to about 8000 cycles per second, it is common practice to divide the frequency range into two or more parts and provide one or more loud speakers for each of these frequency ranges. The speakers employed for the different bands are, of course, differently designed, each speaker being particularly suitable for its own band. Since it is not possible to design loud speakers that will faithfully and efficiently reproduce frequencies in one preassigned band, and sharply attenuate frequencies outside the band, it is necessary to supply an electrical network between the final power amplifiers and the loud speakers to deliver the correct frequency band to each set of loud speakers. These networks have acquired the name of "dividing networks."

In practice, loud speaker systems may be of the two-way or three-way types. Because of the preëminance of the two-way system, only networks for use with such systems are discussed here. For the two-way system the speakers handling the lower frequencies are termed the low-frequency, or low-range, speakers. In like manner, the speakers that reproduce higher frequencies are called the upper-frequency speakers or upper-range speakers. For each of the two frequency bands one speaker unit or a number of speakers are arranged in series-parallel combinations to secure the proper combined load.

Dividing networks are not usually of the sharp cut-off type; that is, they are not arranged to transmit uniformly frequencies of a given band and then attenuate sharply all other frequencies. Rather, they transmit the band frequencies almost uniformly and gradually slope off, thereby providing a certain amount of overlap between the assigned frequency ranges. While theoretically it may seem desirable to arrange dividing networks to cut off sharply, from a commercial standpoint the sharpness of cut-off is necessarily a compromise between expense and effectiveness. For well designed loud speaker systems, the rate of change of attenuation should be sufficient at least to suppress objectionable irregularities in the response of one horn in its transmitting range because of sound coming from the other horn in its suppression range. From an analysis of a large number of speaker systems it appears that dividing networks should provide at least 10 to 12 db. of attenuation one octave away from their cut-offs. In considering networks having greater rates of change of



$$L_0 = \frac{R_0}{\pi f_c} \qquad L_1 = M L_0 \qquad L_2 = \frac{1-M^2}{4M} L_0$$

$$C_0 = \frac{1}{\pi f_c R_0} \qquad C_1 = \frac{1-M^2}{4M} C_c \qquad C_2 = M C_0$$

$$\frac{f_R}{fc} = \frac{1}{\sqrt{1-M^2}} \qquad M = \sqrt{1-(f_c/f_r)^2} \qquad F_c = \frac{1}{\pi\sqrt{L_0 C_0}}$$

$$Z_I = R_0\sqrt{1-(f/f_c)^2} \qquad Z'_I = \frac{R_0}{\sqrt{1-(f/f_c)^2}} \qquad F_r = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$Z_{Im} = \frac{Z_I}{1-(1-m^2)(f/f_c)^2} \qquad Z'_{Im} = Z'_I[1-(1-m^2)(f/f_c)^2] \qquad F_r = \frac{1}{2\pi\sqrt{L_2 C_2}}$$

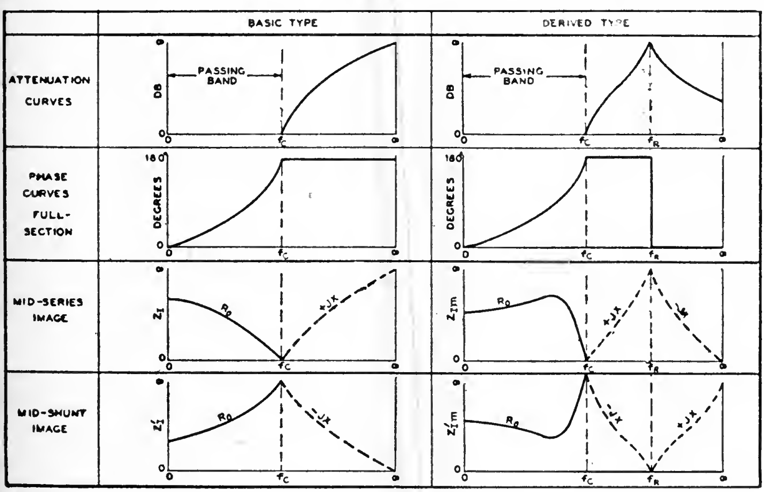
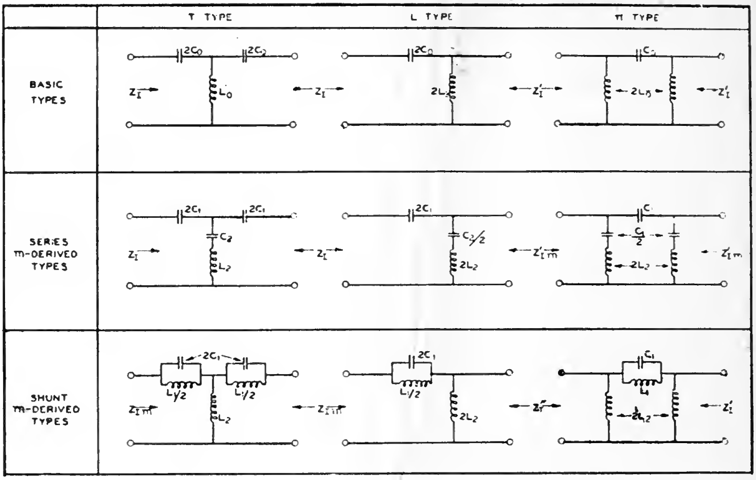


FIG. 11. Low-pass filters.



$$L_0 = \frac{R_0}{4\pi f_C} \qquad L_1 = \frac{4m}{1-m^2}L_0 \qquad L_2 = \frac{L_0}{m}$$

$$C_0 = \frac{1}{4\pi f_C R_0} \qquad C_1 = \frac{C_0}{m} \qquad C_2 = \frac{4m}{1-m^2}C_0$$

$$\frac{f_R}{f_C} = \frac{1}{\sqrt{1-m^2}} \qquad m = \sqrt{1-(f_R/f_C)^2} \qquad f_C = \frac{1}{4\pi\sqrt{L_0C_0}}$$

$$Z_I = R_0\sqrt{1-(f_C/f)^2} \qquad Z'_I = \frac{R_0}{\sqrt{1-(f_C/f)^2}} \qquad f_R = \frac{1}{2\pi\sqrt{L_1C_1}}$$

$$Z_{Im} = \frac{Z_I}{1-(1-m^2)(f_C/f)^2} \qquad Z'_{Im} = Z'_I[1-(1-m^2)(f_C/f)^2] \qquad f_R = \frac{1}{2\pi\sqrt{L_2C_2}}$$

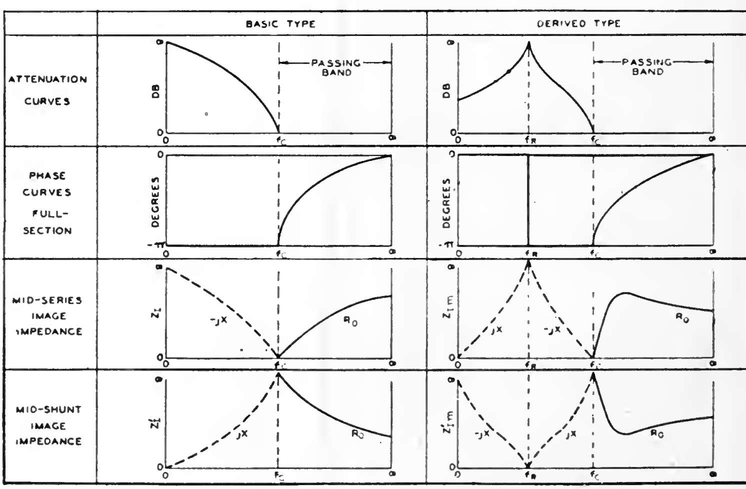


FIG. 12. High-pass filters.

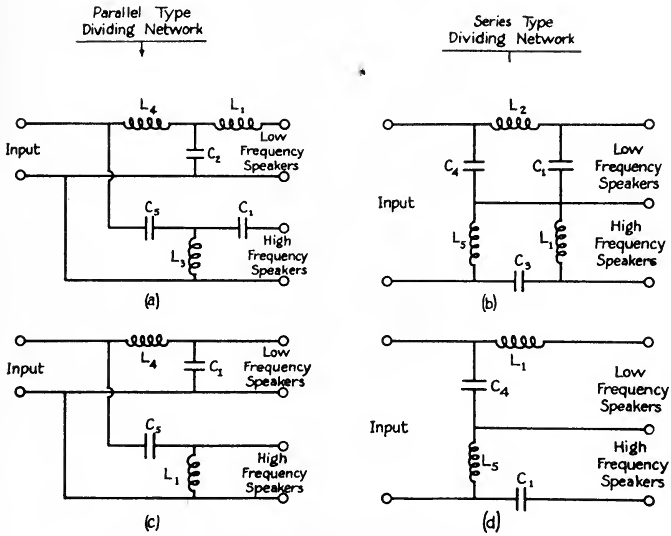


FIG. 13. Filter-type dividing networks.

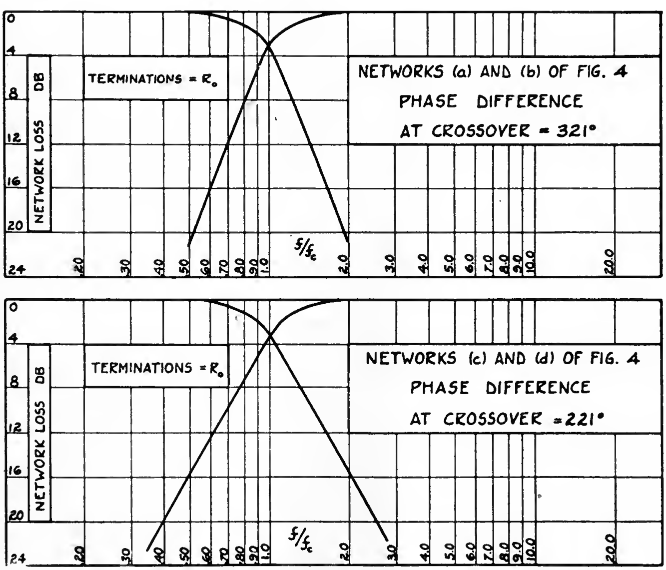


FIG. 14. Transmission loss of filter-type dividing networks.

attenuation it should be remembered that increased attenuation is accompanied by increased loss in the transmitting ranges, which, for high-powered systems at least, is to be avoided. Costs also may mount unreasonably if a large amount of filtering is employed. For these reasons, and considering the magnitude of the irregularities that one speaker produces in the transmitting range of the other, it appears that few dividing networks should employ more attenuation than about 18 db. per octave.

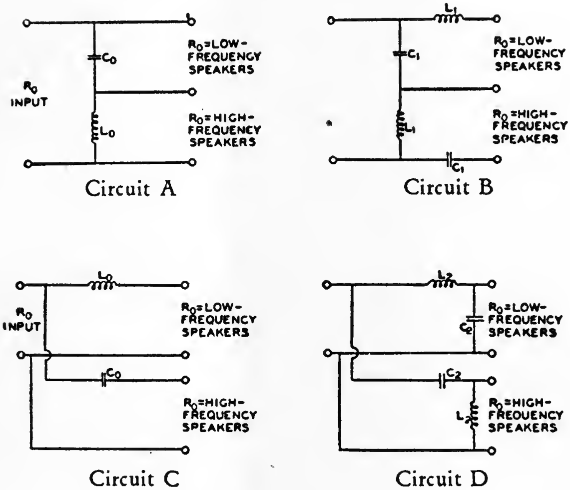
In a two-way system, the frequency at which both sets of loud speakers receive equal amounts of energy is called the cross-over point. In other words, the cross-over point is the point of separation between the two bands of frequencies. In developing loud speaker systems a trial cross-over point is usually arbitrarily selected, keeping in mind the characteristics of the upper- and lower-range speakers that are to be used, and the costs and other items. This point is then later moved one way or the other if found unsatisfactory when the system is operated as a whole.

A two-way dividing network consists of a low-pass filter and a high-pass filter designed to operate from a common source at their input terminals. Two methods are in general use for connecting the filters in series or in parallel at their input terminals; namely, (*1*) the filter method; and (*2*) the constant-resistance method. Each of these methods is capable of good results. The filter method is the more commonly used—probably because it is better known, and is somewhat more flexible in design.

Fig. 13 shows circuits for four filter type dividing networks. Circuits (*c*) and (*d*) are the more commonly used in practice. The symbol R_0 denotes the resistance of the speakers connected to the low-frequency and high frequency terminals. The symbol f_a denotes the cross-over frequency. The transmission characteristics for these networks are shown in Fig. 14.

Fig. 15 shows four types of constant-resistance dividing networks. For these networks, circuits B and D are the more commonly used. Here again the symbol R_0 is used to denote the speaker resistances and f_a indicates the cross-over frequency. These networks measure a constant resistance at the input terminals when the proper loads are connected to the speaker terminals. Fig. 16 shows the transmission characteristics for the different circuits.

Variable Networks.—Networks whose transmission characteristics may be smoothly varied over a wide range by means of a single



$$L_0 = \frac{R_0}{2\pi f_a} \qquad L_1 = \frac{L_0}{\sqrt{2}} \qquad L_2 = \sqrt{2}\,L_0$$

$$C_0 = \frac{1}{2\pi f_a R_0} \qquad C_1 = \sqrt{2}\,C_0 \qquad C_2 = \frac{C_0}{\sqrt{2}}$$

f_a = cross-over frequency of network

FIG. 15. Constant-resistance dividing networks.

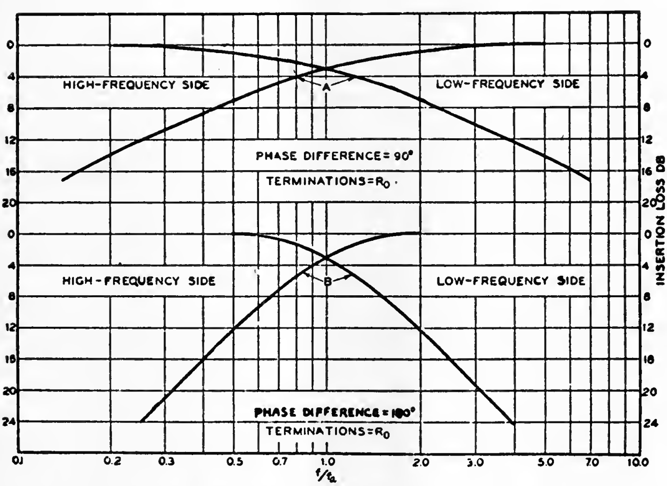


FIG. 16. Constant-resistance network—insertion loss; (*A*) network of circuits *A* and *C*, Fig. 15; (*B*) networks of circuits *B* and *D*, Fig. 15.

control are especially useful in the re-recording work of motion picture studios. At the time, however, the methods available for engineering such networks are not all that can be desired, with the result that occasionally the re-recording mixers are somewhat handicapped in their technic. The requirements for variable networks are three in number: namely, (*1*) minimum loss for the result accomplished, (*2*) constant-resistance impedances at the input and output terminals, and (*3*) a smoothly variable transmission characteristic.

The networks now in use usually attempt partially to meet these requirements by a variety of methods. One common method is to provide constant resistance and minimum loss by varying the transmission characteristic in a step-by-step manner. This is done by multiple switching arrangements to connect to tapped electrical elements. This method results in a complicated mechanical and electrical structure and often introduces noise in the circuit while the step changes are being made. In addition, it is often necessary to compromise on the network design because of the added mechanical difficulties.

Another method in common use is to sacrifice the constant-resistance and minimum-loss features in order to provide a smoothly varying transmission characteristic by means of potentiometer-type variable resistors inserted somewhere in the circuit. Aside from the above-mentioned sacrifices the chief difficulty with this method is that flexibility of design is not realized, with the result that even the transmission characteristic is a compromise. The greatest advantage of this method is simplicity of mechanical and electrical structure.

It is hoped that in the not too distant future a more suitable design technic will be made available for this purpose. Whether this will require the development of entirely new network structures or alteration of existing structures the writer is not able to say.

REFERENCES

[1] "Motion Picture Sound Engineering," *D. Van Nostrand Co.*, New York, N. Y. (1938); ed. by Academy of Motion Picture Arts & Sciences, Hollywood, Calif.

[2] *Ibid.*, pp. 260–272.

MULTIPLE-CHANNEL RECORDING*

H. G. TASKER**

Summary.—*Multiple-channel recording is a device for achieving flexibility at the time of dubbing or re-recording orchestral music presented as such in the picture. If one could predict for the music and sound departments which portions of the orchestra would be seen from which angles in the final picture, or if the editing could be completed before the music was recorded, there would be less merit in multiple-channel recording.*

The reverse is true: The music is recorded first, the musicians photographed later, synchronizing their movements to a play-back of record. Meanwhile, the pictorial treatment has taken partial shape in the minds of producer and director. Still later it takes final shape in the hands of the film editor. Sound and action are then placed in the hands of the sound department for dubbing, but it is then too late for more than an ineffectual raising and lowering of volume. The violins or the woodwinds can not be lifted above the surrounding sections to match a close-up of the picture.

The multiplicity of sound-tracks (recorded, of course, in advance of the photography) provides the dubbing mixer with the means of easily blending a final sound-track that will be wholly in keeping with the final edition of the picture. The application of this method to the recent production "100 Men and a Girl" is described. The use of "close-mix" tracks, separate vocal tracks, etc., in conjunction with multiple recording is also described.

In the case of expensive sound sources, such as symphony orchestras, it has long been the practice to make two or more identical records from a given source of sound by employing two or more recording machines each of which is ordinarily energized from some common point in the amplifying channel but which might equally well be assigned a complete channel of its own. In contrast to this procedure the term "multiple-channel recording" as used in this paper, refers to the use of a number of recording machines each associated with a separate and complete sound channel to make simultaneous records of different aspects of a complex sound source.

A simple form of multiple-channel recording has been practiced in Hollywood for a number of years wherein the vocal effort of a soloist is recorded through one channel while simultaneously the accompany-

* Presented at the Spring, 1938, Meeting at Washington, D. C.

** Universal Pictures Corp., Universal City, Calif.

ing orchestration is recorded through another channel. This procedure affords several advantages which will be mentioned later, but among them is one that inspired the much more extensive multiple-channel recordings that form the principal subject of this paper. This advantage lies in the ability to postpone the "balancing" (that is, the adjustment of relative loudness) of the two principal sound elements (vocal and instrumental) until the picture has reached its finishing or dubbing stage.

The magnitude of this advantage can be best appreciated when it is remembered that musical numbers, especially vocal ones, are almost always pre-recorded. In this method the sound-track is recorded before the picture is photographed, the latter taking place by the process known as "playback" wherein the vocalist sings a duet with herself and each of the instrumentalists plays a duet with himself as the original record is played back on the set during the photographing. This is repeated for as many different angles, close-ups, long shots, *etc.*, as are desired, and as many takes of each as may be required to obtain the desired degree of perfection. Following the photographic step the scene is edited by intercutting the various takes and angles until the best possible entertainment or story values have been incorporated in the scene.

Now, if all our producers, directors, musical directors, and music mixers were supergeniuses, then the music mixer might, by conferring with the others, successfully visualize the exact form that the final edited scene should take, and hence could balance the sound at the time of recording for a perfect interpretation of the scene. Notwithstanding the claims of studio press agents to the contrary, no such degree of genius exists in Hollywood, and every attempt to balance the vocal and instrumental portions of recording for the final editing has proved in some measure disappointing; hence the desirability of postponing the balancing until all the creative work of producer, director, and editor has crystallized in the edited film. This obvious benefit to the rendition of vocal numbers is realized with very little complexity of the recording system since only two separate channels are required, one for the voice and one for the orchestra.

Extension of this idea to the rendition of strictly orchestral music, as for example, a number by a famous band or symphonic orchestra, involves much more complexity because it is desired to feature on the screen from moment to moment various sections of the orchestra, or even individual performers, and to provide acoustic balance ap-

propriate to the scene in all cases. To Leopold Stokowski, famed conductor of the Philadelphia Symphony Orchestra, goes credit for the first application of this method to the rendition of large orchestral numbers in the motion picture production *One Hundred Men and a Girl*. He was not without opposition from skeptics in both technical and non-technical ranks, including those who questioned whether the re-recording machinery could ever synchronize the resulting six or eight sound-tracks to the required degree.

Preliminary study convinced us, however, that this objection was not serious. We had had extensive experience with a technic known as "close mixing," in which a microphone is supplied for each principal section of the orchestra—for example, violins, cellos, woodwinds, brasses, *etc.*—the several microphone outputs being fed to a mixer panel where they are suitably balanced before the recording. In this method the directional properties of ribbon microphones are employed to give best possible separation between the several sections, yet it is obvious that the violin microphone will pick up some of the energy from each of the other sections and each other microphone will do likewise. Since the microphones are placed at an average of eight feet apart there is considerable delay between the arrival of the violin sounds at the violin microphone and its arrival at the other microphones. This is identical in effect to the slight errors of synchronization that might occur in multiple-channel recording and results in a reverberant quality but which is never as severe as is the reverberant effect when recording with a single microphone placed far enough away to be equidistant from most of the sections of the orchestra.

It is obvious that the degree of synchronism need only be comparable to that of the several microphones placed throughout the orchestra. The available degree of synchronism being approximately $^1/_2$ frame, corresponding to about 25 feet of air distance, we concluded, and experience later proved, that no difficulty would be encountered from this source.

In connection with these recordings for *One Hundred Men and a Girl* there was more than ordinary need for such an arrangement to permit postponing the balancing of the orchestra: the recordings were to be made in April for a picture that was to begin production in May; they were to be recorded in Philadelphia for a picture to be photographed in Hollywood; and the scenes in which they would be employed had not yet fully crystallized in the minds of the writers and producer. With these facts in mind, we requested the RCA Manu-

facturing Company to provide at the Academy of Music in Philadelphia eight separate channels. Six were to be used for the simultaneous recording of the several sections of the orchestra, one to record the orchestra as a whole from a pair of overall, or "long-shot" microphones, and one to record the voice of Deanna Durbin with orchestral accompaniment. In view of the considerable expense of assembling the talent and equipment for these recordings it seemed the better part of wisdom to provide one more channel equipped with six microphones and a conventional mixer panel so that our usual close-mixed track could be made simultaneously, as a protection in case anything went wrong with any other part of the system. Each of the separate channels consisted of a microphone, the customary amplifier, and gain controls, and the recording machine; and was manned by a mixer and a recordist. The close-mix channel had six microphones and a six-position mixing panel controlled by Mr. Bernard Brown, head of the music and dubbing section of Universal's Sound Department, who was sent to Camden as our representative for the whole recording operation. The six microphones of the "close-mix" channel were placed as close as possible to the six "separate channel" microphones, respectively. With these arrangements all the symphonic and two vocal numbers for the picture were recorded.

The great merit of multiple-channel recording is especially well demonstrated in this motion picture by the rendition of Liszt's *Second Hungarian Rhapsody* on the staircase of Stokowski's home. The director, Henry Koster, chose to portray a great deal of this scene in a series of "approach" shots to the several sections of the orchestra and to various principals of the story. When the resulting edited picture was experimentally projected with the conventional close-mixed track it was found to be quite "flat" and unconvincing. It almost completely lacked the inspiring vigor that it later acquired as a result of appropriate mixing from the individual tracks of the multiple-channel recording.

While multiple-channel recording, as just described, can yield remarkable results in connection with the rendition of orchestral numbers, the number of such scenes that occur in the course of a year's production in any one studio is relatively small and it could not be expected to find a very extensive field of application unless it were to prove materially helpful in the more common type of musical numbers, namely, vocal. However, the instrumental accompaniment for vocal numbers has little need of the discriminative balancing of

sections from moment to moment because its level must be low enough to accompany the voice of a singer suitably and because individual sections of the orchestra are rarely featured on the screen during such a number.

For these reasons the simple form of multiple-channel recording mentioned earlier has been adopted as the standard method of recording vocal numbers at this studio except for the inclusion of a third channel. On this third channel is produced a combined vocal and orchestral track which serves a double purpose. It affords protection in the event of failure of either of the other two tracks, and provides an immediately available work-track in which the two elements are reasonably well blended.

To simplify the operations of this three-channel system the mixer dial of the vocal channel appears on the same panel with the six mixer dials of the orchestral channel. Their outputs are led separately through their respective channels to their respective recording machines, but by means of bridging amplifiers the third channel plus the mixer's monitor circuit are energized from the combined outputs of the vocal and orchestral microphones.

In addition to the advantage already described for such a system a second important advantage is often gained in that it is not necessary to obtain simultaneously a perfect orchestral recording and a perfect vocal recording plus a perfect balance of each with respect to the other. If, for example, a vocalist is not adequately rehearsed or becomes "out of voice" it is possible to make the instrumental track first and then dismiss the expensive orchestra (often $500 to $700 per hour) and arrange for the vocal recording on the following day or at any convenient time after a choice take of the instrumental track has been developed and printed. In this subsequent recording the vocalist hears the reproduced instrumental track through the headphones and, singing to this accompaniment, repeats the performance so often as necessary until a perfect vocal recording has been made. Especially in the case of young or nervous performers, the total absence of the orchestra and any accompanying high pressure often proves very helpful. Since the orchestral track is not being re-recorded at this time, but will be combined with the vocal track at a later date, arrangements are made to aid the mixer in his judgment of the vocal quality by introducing the desired level of the orchestra into his monitor through bridging amplifiers, so that his basis of judgment is almost identically the same as if the orchestra were present.

SOME UNUSUAL ADAPTATIONS OF 16-MM. EQUIPMENT FOR SPECIAL PURPOSES*

J. L. BOON**

Summary.—*A casual observer, looking over the existing standard amateur photographic equipment, would probably be of the opinion that there is little need of altering a camera to do a special job. However, closer observation of the various problems that photography serves reveals that the standards of practice have been chosen merely to suit the needs of a common majority of users, and the minority are almost forgotten. Further observations show that an alteration to a standard camera to make it fit a specific purpose usually precludes its usefulness for many of the purposes for which it was originally designed, and also its utility for other special purposes.*

In this paper are made known some of the unusual adaptations of 16-mm. motion picture equipment, each to fulfill a definite purpose, and it is shown that industry is becoming more conscious of the utility of such photographic equipment as tools in solving some of its problems.

A casual observer looking over the existing standard amateur photographic equipment would probably be of the opinion that there is little need for altering a camera to do a special job. However, closer observation of the various problems that photography serves reveals that the standards of practice have necessarily been chosen primarily to suit the needs of a majority of users. Usually an alteration to a standard camera to make it fit a specific purpose precludes its usefulness for many of the purposes for which it was originally designed and also its utility for other special purposes.

At one time some of the features now included on standard motion picture equipment, such as speeds other than normal, lenses of various focal lengths, variable shutter openings, *etc.*, would have come within the scope of this paper. The incorporation of these features in standard cameras, however, has not decreased the inflow of requests for equipment for special uses.

Extension of Camera Speed Range.—Fortunately, the simplest form of alteration is the one most often requested, that is, the ex-

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 19, 1938.

** Eastman Kodak Co., Rochester, N. Y.

tension of the speed range. At one end of the range, exposure intervals of as long as one per day would be useful. If the long interval is also a fixed interval, a simple method of achieving the result is to let a continuously running synchronous clock motor wind a small coiled spring one turn per fixed time interval, at the completion of the turn releasing the spring, which then drives the camera shutter

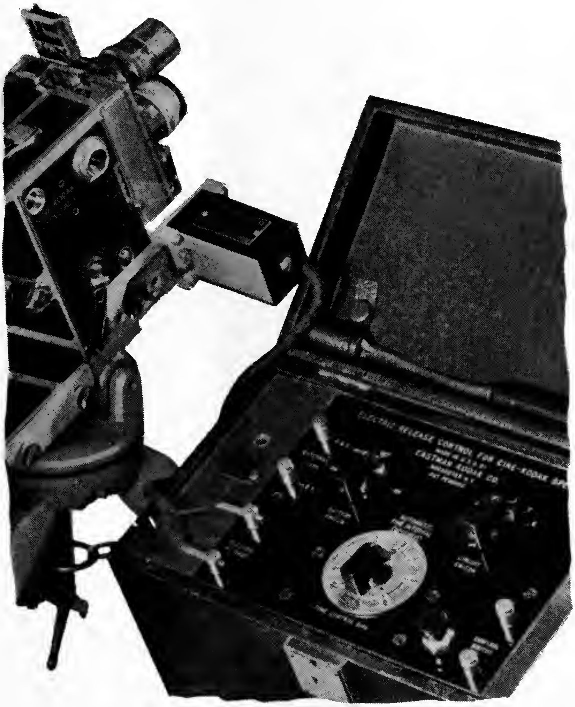


FIG. 1. Electric release and control for making exposure at variable intervals.

and pull-down through one revolution, exposing and advancing the film. The motor may also close a light circuit for illuminating the subject during the exposure interval. If greater accuracy of timing is required than such an arrangement permits, the motor is stopped after one turn of spring winding, and an external impulse releases the spring for driving the camera and also starts the spring-winding motor. Another method proposed for limited use is to enclose the camera and subject in a light-tight box, moving the film continuously or

intermittently. The exposure is made by flashing a light by means of an accurate external source. The resulting film would probably be unsatisfactory for motion picture projection, but individual frames could be viewed or enlarged.

A variable-interval device operating automatically has been manufactured for the Cine Kodak Special (Fig. 1). Timing is accomplished by means of a condenser discharge operating a relay, which in turn sends an electrical impulse to a solenoid on the camera single-frame shaft. The camera spring furnishes the driving power for the mechanism; the solenoid merely allows the single-frame shaft to make one or one-half a turn. Batteries are included with the control box,

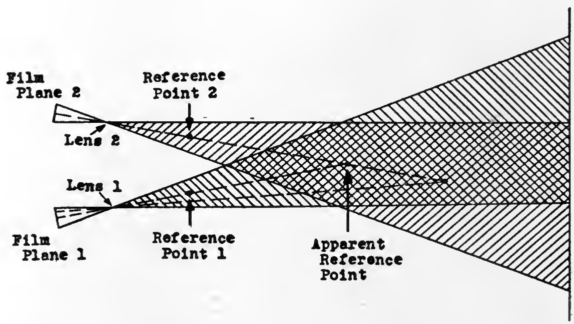


FIG. 2. Plan for taking pictures of take-off and landing of airplanes, showing image displacement for two distances (not drawn to scale).

eliminating a further source of power. A secondary interval multiplier increases the interval range at the longer end.

Although there are many uses for cameras with long intervals between exposures, the majority of requests are for cameras that operate at speeds greater than normal. Many motion picture cameras, other than those for sound, will operate at 64 pictures per second. For most motion analysis this speed merely indicates what might be learned if higher camera speeds were used. It is not very difficult to drive a camera at 120 frames per second, but driving it on batteries with a speed variation of less than 0.5 per cent is somewhat more difficult. It was done, however, by using a synchronous motor for driving the camera; and by changing the gear ratio between the motor and the camera, various camera speeds were attained, each within close tolerance.

Photographing Airplane Take-Off and Landing.—A method was devised for the Department of Air Commerce for measuring the distance and altitude of an airplane as it makes a take-off or landing.[1] Two Cine Kodak Specials sixty feet apart, or multiples thereof, were used to photograph the runway (Fig. 2). It was found that pictures taken at the rate of four per second gave satisfactory readings. This speed could be attained readily and synchronously by using a solenoid release on each camera and operating both on a single impulse from the control box. Matched lenses of $2^1/_2$-inch focal length were used. The cameras were slightly "toed in" to converge in field at a distance

FIG. 3. Side view of twin projectors used in taking data from pictures of the take-off and landing of airplanes.

of 1600 feet for the 60-foot base line, 3200 feet for the 120-foot base line, *etc.*

It was necessary to build a special twin projector for taking readings from the film, since slight displacements of the airplane images on the two films had to be measured at the same time (Figs. 3 and 4). A separate projector is used for each roll of film of the pair, but both films are advanced frame by frame by a common drive, so that right and left pictures move in synchronism after they have once been set in matched pairs. Geneva drives are used and the film is held in the gate between glass plates which separate as the film is moved. The lens on one projector is movable horizontally and that on the other vertically so that corrections may be made for slight film displacements. All the controls are operated from the viewing side

of the two adjacent translucent projection screens. The two images of the airplane taken at the same time gradually separate as the airplane moves farther away. This separation is measurable directly in feet by means of a special transparent scale at the projection screen, to a distance of about 2500 feet with a 60-foot camera base line. From the distance reading, the altitude is also read directly on the scale. The camera base line may be increased so that distances of more than 2500 feet are readable on the scale.

A "Shutterless" Camera.—In making a motion picture camera for recording a subject of low intensity, such as the x-ray image on a

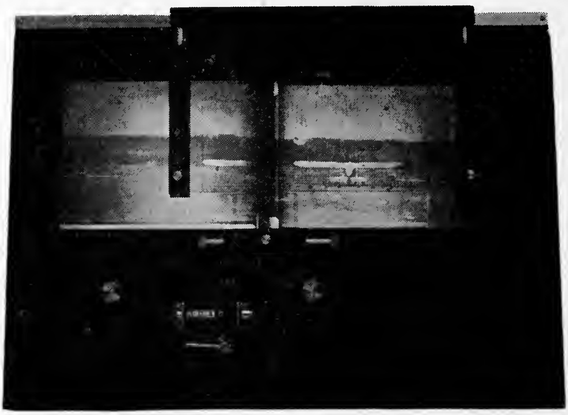


FIG. 4. Screen and direct-reading scale for measuring altitude and distance of airplane.

fluorescent screen, it is not only necessary to use the fastest lens and film available, but also a shutter of almost 100 per cent efficiency; that is, no shutter at all. This means that the pull-down time must be less than 5 per cent of the exposure time to eliminate travel-ghost. A spring was attached to the pull-down claw in such a way as to accelerate its film pull-down motion. An overrunning clutch was attached to the pull-down shaft to prevent any chance of reverse motion of the pull-down. The shaft is independent of the drive in its forward motion, but the motion ceases at completion of the pull-down stroke; until a driver, which runs concentrically with the pull-down shaft and which turns at a definite speed, catches up with it and rotates it through the remaining half of the stroke. This driving also stretches the spring to full tension so that it is again in position to

accelerate the pull-down of the film when the driver rotates the pull-down shaft a little beyond dead center. The tension in the spring determines the pull-down speed, and the exposure time is approximately the reciprocal of the number of pictures taken per second. It was thought that 8 pictures a second would be the most satisfactory compromise, and in order to project these pictures at the taking speed without flicker, a projector was altered to give 48 shutter interruptions at a film speed of 8 frames a second. This could be done without destroying the balance between blurring and stuttering of the screen image, since the motion photographed is somewhat slower than normal. Alterations in the projector involved doubling the shutter shaft speed with respect to the pull-down up-and-down motion and a change in the in-and-out pull-down motion to decrease the time that the pull-down claw is engaged with the film.

Abnormal Picture Proportions.—Requests for abnormal picture proportions have been few but are usually well founded. A recent

FIG. 5. Stereoscopic pictures on 16-mm. film mounted in a cassette.

one was for motion pictures on 16-mm. film with the height-to-width ratio changed from 3 × 4 to 4 × 3. This could be accomplished quite easily by photographing with the camera on its side. The problem of altering a standard projector to give an erect image was a bit more difficult. Prisms or mirrors in the optical path were tried and found satisfactory under laboratory conditions but were subject to strain, collected dust, and caused considerable loss of light. This led to trying the same trick on the projector as on the camera, that is, turning it on its side. The lamp house was rebuilt so that the lamp burned in a vertical position, and the supporting base was remade to suit the conditions. In general, this has proved quite satisfactory, and it is thought that slight unsteadiness, which, of course, shows up horizontally instead of vertically, is less noticeable.

The same customer requested also a means of photographing a subject, making several thousand small, still pictures in color in a short period of time, and projecting ten or twelve pictures of different subjects on a translucent screen with an automatic means of changing

the picture after a fixed time interval. Although these pictures were to be used as stills, it seemed necessary to take them in a motion picture camera, since they had to be made in a short period of time and were to be in color. The most satisfactory height-to-width ratio was found to be 3 to 2. On 16-mm. sound-film, the maximum width that can be used for pictures is about $^1/_2$ inch, which would make the height about $2^1/_2$ frames. Allowing tolerance for mounting, a little more than three frames was desirable for each picture. With this much known, alterations on a Cine Kodak Special were begun. The aperture in the gate was increased in width and height, the pull-down stroke doubled, the sprocket speed doubled, and the shutter speed cut in half. With the increased angle subtended by the aperture from the shutter center, it was necessary to decrease the shutter opening. Exposure with the camera running at four pictures a second is about the same as with a normal 16-mm. camera at normal speed.

Two cameras of this type were built to operate side by side from the same power source, doubling the output or making stereoscopic pairs. The film could be processed normally and the individual pictures cut to fit die-cast cassettes (Fig. 5). These cassettes hold ten pictures or five pairs of stereoscopic pictures, each stereoscopic pair being mounted with interocular separation. The cassettes then serve two purposes. They may be used in a simple stereoscope for single-station viewing, or projected singly upon a screen. The projector built for the latter purpose consisted of lamp house, condenser, and projection optics, translucent screen, and the cassette carrier and associated mechanism. The mechanism allows each picture to be projected for about eight seconds and then advances the cassette holders for the next picture to be projected.

The Eastman high-speed camera,[2] the race-timing camera,[3] and the associated rapid developing and enlarging unit[3] have already been described in the JOURNAL.

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AN IMPROVED ROLLER TYPE DEVELOPING RACK WITH STATIONARY DRIVE*

C. E. IVES**

Summary.—*In a previous paper a rack was described that provided for continuous motion of a 200-ft. length of motion picture film during processing but could be used with the rack-and-tank equipment. The purpose of this roller rack was to give a type of treatment in processing essentially similar to that given by a continuous machine while retaining the features of batch equipment that are helpful in experimental processing.*

The rack previously described included a built-in driving motor and reduction gear, an arrangement that was most feasible for a single unit. With more extensive use it became desirable to have multiple units operated from stationary drives at the tanks and at the loading and unloading stations.

A new design has been worked out in which the weight of the rack was reduced greatly by the use of stationary drives. Further reduction in weight was attained by the substitution of tensioning springs for the weighted supporting beam associated with the movable lower shaft in the earlier model. This shaft was mounted upon the frame by lever arms in such a way as to use the torsional rigidity of the shaft itself to maintain it parallel to the upper shaft while allowing it the necessary vertical movement.

In an earlier paper[1] a rack was described which provided for continuous motion of a 200-ft. length of motion picture film during processing and which could be used with rack-and-tank processing equipment. The purpose of this rack was to facilitate the conduct of experimental work by the provision of a type of treatment similar to that given by a continuous processing machine with equipment which could be used under conditions of batch operation favorable to frequent change of developer and time of treatment.

The film was carried in a helical path over a succession of rollers at the top and bottom of the rack, the upper and lower rollers each having a common shaft. In order to permit continuous motion in one direction, the film strands from the ends of the helix were joined to form a closed loop. The return strand so formed was located

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; Communication No. 671 from the Kodak Research Laboratories.

** Eastman Kodak Co., Rochester, N. Y.

along the bottom of the rack. Thus, starting at one end, the film reached the other end of the rack by following a helical path, turning around rollers along the top and bottom, left the last upper roller to go to the lower corner of the rack while making a quarter turn, traversed the length of the rack on the supporting rollers along the bottom, and then after making another quarter turn arrived at the starting point. The drive motor and reduction gear were built in.

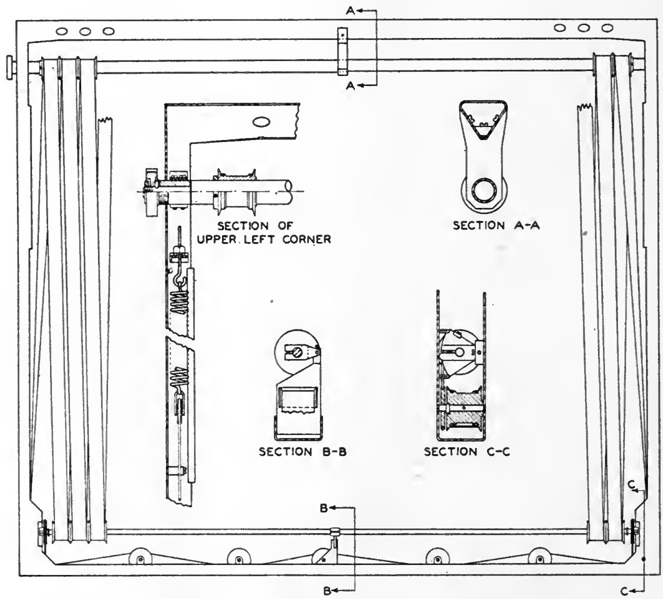

FIG. 1. Elevation of new roller type of developing rack.

This rack was found to fill a definite need and consequently was used extensively. With an increasing volume of work it became necessary to have additional units in service. An opportunity was, therefore, presented for making certain improvements in design and reducing the weight of the rack.

Desirable Features.—After reëxamination of the features of the existing rack, it was concluded to provide for a 210-ft. film length with the same film path, the completely submerged film path being retained.

A running speed of approximately 150 feet a minute was thought desirable in order to simulate continuous machine conditions and to

obtain some improvement in development uniformity. The higher speed would also have the particular advantage with the roller rack of assuring greater uniformity of treatment throughout the 200-ft. length by increasing the number of times the whole path was traversed during development.

With multiple-rack operation it would be practicable to install driving means at the processing tanks and at loading and unloading stations, thus making possible the removal of the drive from the rack with a considerable reduction of weight of the latter. Drives located at the processing tanks would be partly submerged in the bath so that the design would have to dispose of the problems of corrosion, contamination, and leakage.

Accommodation for expansion of the film when wetted and provision for redistribution of slack would have to be furnished by movement of one of the shafts in the vertical direction under tension, while it was maintained parallel to the other. The use of a slide or track for this movement should be avoided because of the friction introduced.

The rack frame should be rigid and light in weight and should have clean lines and an open construction favorable to quick drainage of the solutions. The presence of mechanical parts other than the rollers within the film loops was considered sufficiently objectionable to warrant a redesign of the evener mechanism.

In order to be used with existing tank equipment the rack should not exceed 2 inches in width and 54 inches in length. The height should be about 48 inches. The improved rack is illustrated in Fig. 1 and its features are explained by means of the figures and description which follow.

The Driving Shaft.—In order to obtain a compact and simple drive unit it was decided to drive through the upper shaft and maintain the film loops taut by means of a spring-tensioned movable lower shaft. With the driving unit located at one end of the tanks near the top, it was necessary only that the upper shaft be extended slightly beyond the end of the rack and fitted with suitable means for engagement with the drive gearing. In order to obtain immediate starting and a simplicity of manipulation fitted to working in total darkness, direct engagement with the running drive was decided upon. A means of accomplishing this, described by White in an article on equipment for testing motion picture film,[2] was considered for the present purpose but did not lend itself well to use in the $2^1/_4$-inch

space available. The design chosen consisted of direct engagement (radially) of two spur gears at a peripheral speed of about 200 feet a minute. Good service has been obtained with a 12-pitch, 22-tooth, $^1/_2$-inch face gear of reinforced bakelite on the rack and a similar, slightly wider stainless steel gear on the drive. The bakelite gear has undergone some wear under this shock loading during $1^1/_2$ years of use but is still in service. Wear on the steel gear has been negligible.

The upper shaft consists of a 1-inch outside diameter ground stainless-steel tube closed at both ends. It is supported by three plain bearings of reinforced bakelite which receive the required lubrication from the processing liquids. The bearings at center and right in Fig. 1 are for axial loads only, all thrust being taken by the bearing at the left. At this point the shaft diameter is stepped down to $^7/_{16}$ inch by means of an extension piece which is sweated into the tube. Beyond the bearing to the left is the bakelite gear which is held in position from one side by a pin through the shaft and on the other by a jam nut and lock washer.

This end bearing is fastened by screws to a bracket on the frame. When the screws are loosened the shaft can be passed, with the gear in place, through an opening in the end frame member of the rack to permit removal of rollers at the opposite end of the rack. The bearing block is extended $^5/_{16}$ inch outside the frame, where it is turned to a cylindrical shape to act as a trunnion, by whose engagement with a guide plate on the drive unit the gear center distance is maintained.

Film Supporting Rollers.—In the model described previously, in which hard-rubber rollers were used, only one flange to the roller was used to save space. At the present time rollers are made of reinforced bakelite which is sufficiently strong to permit the use of much narrower flanges. This, in combination with other changes in the frame providing additional space, has made possible the use of double-flange rollers, with a resulting improvement in film guiding.

All rollers are equipped with soft-rubber treads which eliminate the scratching usually seen along the perforation track of machine-processed film. These treads grip the surface of the film support very strongly so that, when slack is being redistributed along the rack, any slippage must be between the rollers and the shaft. At the same time it is necessary to apply some driving force over and above that furnished by the friction between the rollers and the shaft. This additional friction is furnished by the use of six rollers with friction-

drive pads of the type shown in Fig. 2. The pads are pressed against the shaft by the arcuate flat stainless-steel spring with sufficient force to require a tension of eleven ounces at the film line to cause slippage. The lower shaft rollers are similar to the remaining upper rollers except for the bore.

The Lower Shaft.—Differences in the expansion of various materials when wetted, as for example, coated film and uncoated leader, cause looseness of the film at one point or another along the rack. Redistribution of this slack is brought about by compelling the lower shaft to remain parallel to the upper shaft while it moves up and down. If parallelism is maintained, then any slack which appears while the film is running is immediately redistributed, because the shorter strands receive the full tensioning force applied to the shaft.

FIG. 2. Drive roller with auxiliary friction pads.

In the previous model the required downward force was provided by the weight of a heavy stainless steel beam which supported the shaft at three bearing points. Two extension coil springs of stainless steel supply the tension in the new model. The most suitable location for the springs is in the channel members forming the upright rack ends (Figs. 1 and 3). Here they are suspended from an adjustable screw while the spring tension is transmitted to the movable shaft by means of a 7 × 7, $^1/_{16}$-inch diameter stainless-steel stranded cable. The cable is anchored to the frame just below the spring, passes over a pulley block suspended from the latter, from which point it goes to the bottom corner of the rack, and, after passing under a sheave, reaches a quadrant affixed to the movable lower shaft. This cable is strong, economical of space, and tolerant of slight misalignment.

Mechanism for Obtaining Parallel Shaft Movement.—With the elimination of the lower shaft beam and the old type of parallel motion gear, both of which were formerly located above the lower shaft within the film loops, a new means of supporting the shaft and of effecting

parallel movement was required. It was found that the shaft itself, although so slender as to have little beam strength, was of suitable proportions to act as a quite rigid torsional evener.

The operation of the evener is described conveniently by reference to Fig. 3, which shows schematically the lower shaft mechanism and spring-tensioning system. The shaft is clamped at three points in crank arms (see also Fig. 4) which pivot on three pins supported by the frame on a common horizontal axis. Downward pull to hold the film loops taut is applied by the cables which are fastened to the quadrants associated with the cranks at the ends of the shaft.

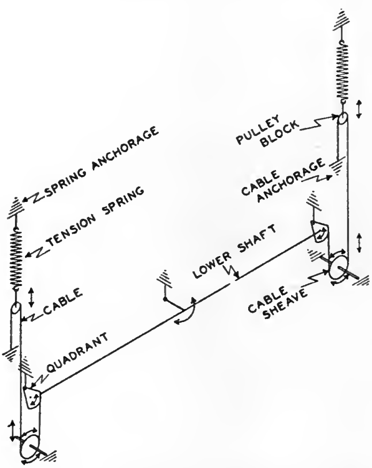

Fig. 3. Schematic representation of parallel movement mechanism and tensioning system.

Vertical movement of the shaft caused by a change in the length of the film loops results in movement of the cranks about the pivots and a corresponding rotation of the shaft. Thus, if one end of the shaft is lowered slightly with consequent rotation about its axis and the other is held up by a shorter film loop, the torsional rigidity of the shaft tends to cause a corresponding rotation at the latter point as well. Rotational force at the attached crank causes, in turn, an increased downward tension upon the short loop and thus brings about the desired redistribution of the film on the rack. For a small displacement, the movement employed may be compared to that of a shaft carrying three pinions moving along racks. The rigidity of the stainless-steel shaft of $^3/_8$-inch diameter is sufficient to transmit the 16-pound force through the length of 48 inches with less than 0.1-inch vertical displacement. With this tension applied at each end, any slack is immediately redistributed.

Bowing of the shaft is prevented by locating another crank and pivot at the midpoint which employs the torsional strength of the shaft in the manner described above to maintain the shaft at the point of attachment approximately in line with the shaft ends. With a 0.812-inch distance between crank centers and a vertical movement

of about 0.923 inch, the lateral movement is only 0.144 inch. The spring design is such that the tension changes only 20 per cent with the full vertical movement of the shaft.

The Return Path.—As formerly, the path by which the film returns from one end of the helix to the other is located along the bottom of the rack. The seven supporting rollers are carried within the bottom frame member on shafts fastened to the sides of the channel by means of countersunk screws. For removal of the screws the shaft can be held by a pin inserted in a hole in the roller and shaft.

The Frame.—The frame is made entirely of 16-gauge stainless-steel sheet stock and comprises four principal members. These are of channel form for the bottom and the two upright ends, and triangular for the top piece, providing for rigidity and convenience in lifting the rack from the tanks. These parts and the lower corner gusset plates are assembled by butt welding. Brackets are attached by spot welding. The weight of the frame was reduced slightly by punching out holes in the larger surfaces. The frame is sufficiently rigid for the mechanical movements employed.

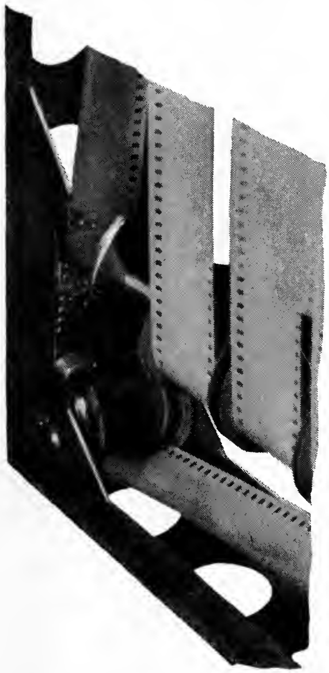

FIG. 4. Close-up of lower corner of rack.

Drives on the Tanks.—The tanks in which the rack is used have dimensions of 60 inches in length, 54 inches in depth, and either 6 or 10 inches in width. To avoid difficulties in alignment and to obtain a simple drive presenting a minimum contamination and corrosion hazard, individual splashproof motors were mounted on each tank (Fig. 5). The only points receiving oil lubrication are the well guarded motor bearings. Direct speed reduction from the 1150-rpm. motor shaft to the 385-rpm. rack drive gear in the bath is obtained through a chain drive. A 9-tooth sprocket is mounted on an extension of the motor shaft. The $^1/_8$-inch, $^1/_2$-inch pitch roller chain engages this and the 27-

tooth sprocket on the drive gear. These parts are of stainless steel. The drive gear has a combination bushing and thrust washer of reinforced bakelite which runs on a stainless-steel stud with the processing solution for lubrication. This gear is held in position by the stainless-steel apron which covers all of the moving parts and acts as a splash and safety guard. The apron is entirely open at the bottom to facilitate cleaning.

Racks are guided into the tank (Fig. 6) by the strips welded to the

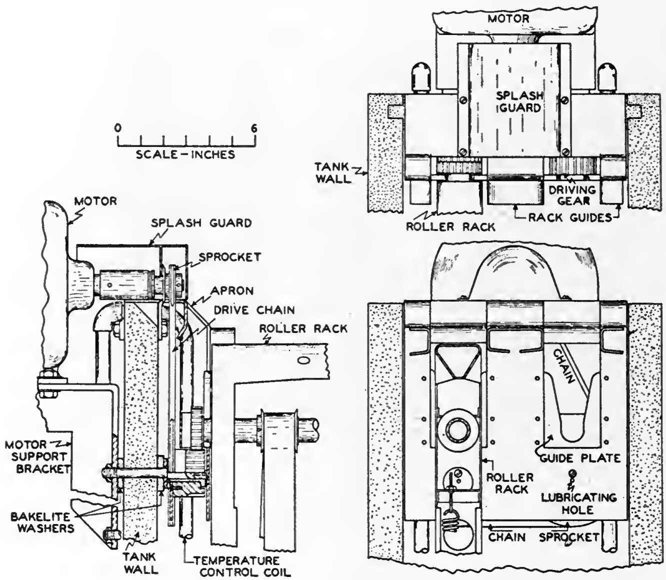

Fig. 5. Drawing of drive unit on tank.

face of the apron. Correct positioning of the rack gear relative to the drive gear is maintained by causing the rack trunnion to rest in the recess in a guide plate fastened to the apron. The rack is also supported at the diagonally opposite bottom corner where a shelf is located a few inches above the tank bottom. Angular misalignment of the gears in the horizontal direction is limited by the rack guides at the opposite end of the tank to approximately 1 degree in either direction, which is acceptable for the purpose. Space is provided for temperature control pipes which enter back of the apron.

The Loading Station.—At another point in the developing room a drive is installed for running the rack while it is being loaded (Fig. 7). In this case a reduction gear of conventional design is used, since the corrosion and contamination problems are not severe. To facilitate locating the rack on the loading stand, guides are mounted behind the rack position near the drive and at the supporting shelf at the bottom.

Loading is carried out by opening a splice in the leader with which the rack is always threaded when not in use, and then attaching the film to one of the ends. The drive is started, causing the film to be led onto the rack while the leader is taken up on a rewind at the point

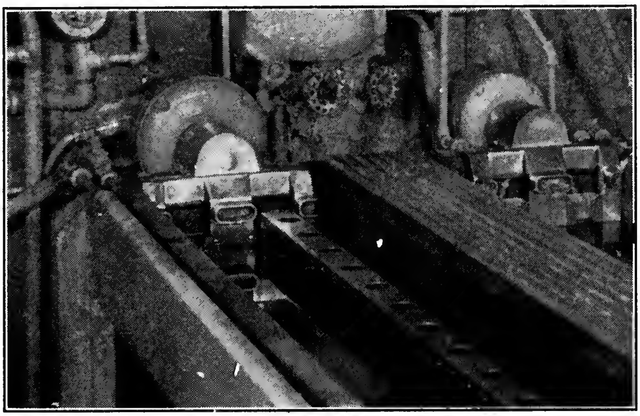

FIG. 6. Tank with rack in position.

where it is leaving the rack. In this operation and later when the rack is being unloaded, a guide roller with soft rubber treads (visible at the top of the rack in Fig. 7) is brought into bearing against the edge portion of the film at the point where the leader or film is leaving the rack. This assures sufficient contact of the film with the roller on the rack to provide the necessary drive. The guide roller is carried by a resilient mounting which is slipped onto the upper frame member when needed. A friction hold-back on the feeding roll is adjusted to maintain enough tension in the entering film strand to prevent the lower rack shaft from rising or falling. Operation of the drive motor is controlled by a foot switch. The maximum loading speed is 200 feet a minute.

Splices are made by means of metallic clips put in by a hand-held device. Reasonably accurate alignment is required for proper running of the film but perforations are not registered.

The Unloading Truck.—The processed film is passed through a portable pneumatic squeegee[3] and transferred to reels for drying. During this operation the rack is carried on a movable truck (Fig. 8) equipped

Fig. 7. Rack threaded with film standing in the loading station.

with a drive similar to that used on the loading station. As the film is removed leader stock is fed in from a stock roll carried on the truck. The motor is controlled by means of a portable switch cord which the operator can attach to his clothing. Running speed is limited to 100 feet a minute or less by the capacity of the squeegee.

Operating Procedure.—The loading operation is managed in such a way as to maintain the movable shaft in the upper half of its range of movement.

Positive, negative, and sound developers are used. Development is timed by the use of an electric darkroom clock with an error of less than 5 seconds. The rack is handled by two men. The rack is continuously driven in the stop-bath and fixing bath, but the film is advanced on the rack only occasionally in the course of washing.

When picture negative film is developed, there is a tendency to form airbells on the emulsion[4] at the point at which the bottom roller enters the developer. They can be dislodged during the first minute of development by holding a soft pad of absorbent cotton lightly against

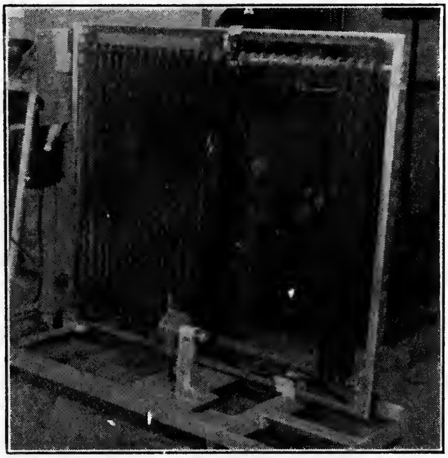

FIG. 8. Rack on unloading truck in drying room.

the emulsion surface at one or two points near the upper shaft rollers; or better, a soft rubber sponge of good quality cut to form a strip $1^3/_8 \times 3 \times {}^1/_2$ inch may be used. It is undesirable to have porous material such as this attached to the rack because of the danger of contaminating the film or developer with hypo.

Performance.—Good uniformity of processing has been attained because of: (*a*) the high running speed of 150 feet a minute, (*b*) the strong agitation of the developer by compressed air, and (*c*) the use of an acid stop-bath.

Acknowledgment.—The assistance rendered by Mr. J. R. Turner and Mr. E. W. Jensen in working out several features in this new design is gratefully acknowledged.

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NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A CONTINUOUS OPTICAL REDUCTION SOUND PRINTER*

M. G. TOWNSLEY AND J. G. ZUBER **

Sound has been commercially recorded on 16-mm. film by a variety of methods, including direct recording on 16-mm. negative, re-recording from 35-mm. negative to 16-mm. positive, and optical reduction from 35-mm. to 16-mm. Any of these methods that involve recording on 16-mm. film are subject to severe losses in frequency response due to the slit effect in recording. Batsel and Sachtleben[1] show this loss to be approximately 12 db. at 5000 cps. for an 0.5-mil slit.

Optical reduction prints may be made either by making an optically reduced negative from a 35-mm. positive and printing by contact, or directly from a 35-mm. negative to a 16-mm. positive. The overall frequency response is nearly the same for either method, since the slight gain in contact-printing the 35-mm. positive offsets the 16-mm. contact-printing frequency losses. Contact printing tends to introduce the further difficulties of uneven slippage and poor contact, which adversely affect the sound quality. This consideration, together with the obvious advantage of economy of materials and time, indicates the desirability of making 16-mm. sound-track prints by direct optical reduction from the 35-mm. negative.

The present paper describes an optical reduction printer having several new features designed to facilitate operation and improve the quality of the finished sound-track. The printer departs from conventional design in that the film rolls, instead of being arranged in a vertical plane, are horizontal. This construction has resulted in considerable simplification in design, and presents important advantages in the operation of the printer. Oil-damped filters and flood-lubricated working parts are made possible without the use of friction-producing oil seals. There is no possibility of lubricating oil reaching any part of the film path. Several other advantages of the construction will be apparent from the following description.

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 18, 1938.

** Bell & Howell Company, Chicago, Ill.

Fig. 1 shows the external appearance of the complete printer. The 16-mm. positive is at the top of the machine where it is readily accessible for threading. Each film roll rests upon a driving flange. The negative feed and take-up flanges are on the same spindles as the positive flanges. The covers *A* are placed over the negative film during printing to protect it from dust and other possible damage. Since the printer is designed to print alternately from beginning and end of the

FIG. 1 View of complete printer.

negative, and is arranged to stop at the end of the negative with the leader still threaded, it is necessary to have access to the negative only when changing negatives. A negative, once threaded, remains in the printer without further attention until the complete run of positives has been made. A pre-set stop mechanism stops the motor at the end of the negative and sets the reversing

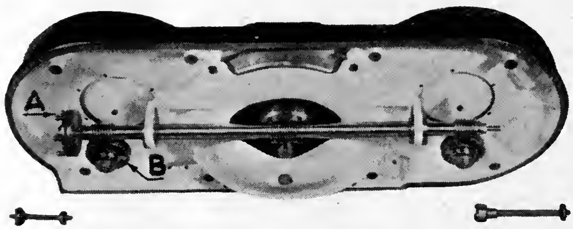

FIG. 2. Main drive assembly without motor.

switches so that at the next starting the machine will operate in the reverse direction.

Fig. 2 shows the main drive assembly without the motor. The entire mechanism is driven from the main worm shaft, which is coupled to the motor by a safety clutch to protect the motor and working parts in case of jamming in the mechanism. The printer is reversed by reversing the 3-phase 220-volt synchronous motor. The printing speed is 60 feet of 35-mm. film per minute. All

the driving gears are flood-lubricated by oil carrier gears which dip into the oil and carry it to the gear teeth.

The flywheel is driven by the central worm, and the take-up spindles are driven by the two worm gears *B*. Unidirectional clutches are arranged so that the take-

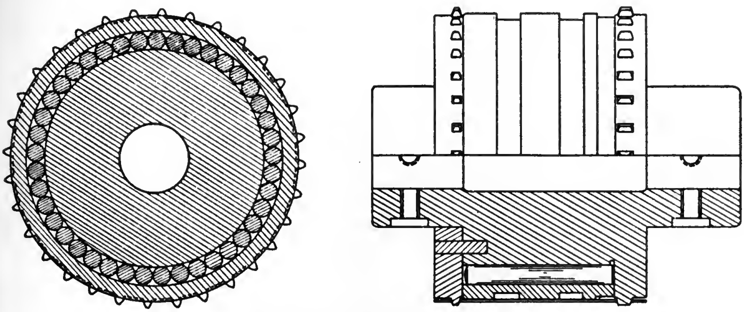

FIG. 3. 35-mm. sprocket.

up spindle is driven and the feed spindle remains stationary. Hold-back and take-up tension is maintained by "arguto" washers upon which the film flanges rest, the weight of the film supplying the major part of the friction. This construction maintains very uniform film tension throughout the length of the film roll.

Uniform film motion is the most important condition imposed upon an optical reduction printer. The excellence of the finished print depends entirely upon

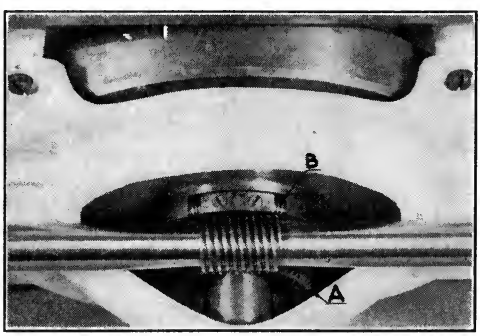

FIG. 4. Flywheel worm drive.

driving the positive and negative films past the printing point at the proper relative speeds, synchronized frame for frame, and without flutter or other improper motion. Synchronization requires that the two films be driven by positively connected sprockets. Uniformity of motion is attained most readily by means of a flywheel, carrying the films at the printing point on toothless drums. Shrinkage

differences between positive and negative and variations in negative shrinkage make it impossible to connect the positive and negative film drums rigidly. Printers embodying various devices to reconcile these requirements have been described in the literature from time to time.[2,3,4]

In the present printer, synchronism is achieved by mounting the sprockets in pairs, a 16-mm. and a 35-mm. sprocket to a pair, each pair on a common shaft. Each sprocket shaft is driven from the flywheel through helical gears. Slippage of the film over the root of the sprocket teeth is prevented by the two-piece construction of the sprockets (Fig. 3). The film is supported by a cylinder slightly larger than the root-circle of the sprocket and free to rotate upon needle bearings on the sprocket itself, so that the film clears the root circle by approximately 1 mil. This construction enables the film to move over the sprocket, as it must to accommodate for shrinkage, without sliding contact, thus preventing scratches. In addition, supporting the film over its entire width reduces the strain on the edges of the film and prevents negative breakage.

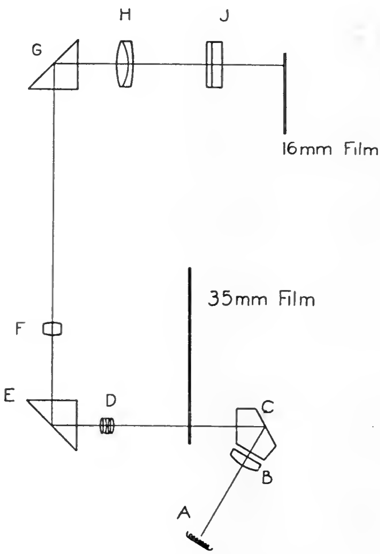

FIG. 5. Optical layout.

A massive flywheel and an oil drag drive are employed to insure exact uniformity of motion of the film by a combination of "brute force" and viscous filtering. The large mass of the flywheel makes it impracticable to drive the flywheel by the film. Instead, the driving motor drives the flywheel through the worm and gear shown in Fig. 4. Worm gear *A* is free to rotate upon the flywheel shaft which it drives through filter springs *B*. The natural period of oscillation of this assembly is sufficiently low effectively to prevent transmission of any possible motor or gear-tooth disturbances to the flywheel. Each printing drum is independently coupled to the flywheel by oil friction. This coupling consists of an interleaved set of thin plates, alternately connected to flywheel and film drum, and immersed in heavy oil. This coupling permits slow relative motion between the positive and negative films to accommodate for negative shrinkage. There will be a constant uniform relative motion between the two drums in direct proportion to the deviation of the actual negative shrinkage from the shrinkage for which the drums are designed. While permitting this necessary slow relative movement, the viscous coupling completely eliminates any flutter or wow from sprocket teeth, splices, or film imperfections by offering very high resistance to sudden movements. The area of contact and the film tension are sufficient effectively to prevent slipping of either film over its drum.

Tension is maintained by spring-loaded idler rollers between the sprockets and

drums. Instantaneous response to film disturbance results from keeping the mass of the rollers as small as possible. Any disturbance is taken up by movements of these idlers and bending of the film without affecting the film drum except by a slow drift.

Positive and negative films are guided by these rollers, the positive film on the edge and the negative by the perforations adjacent to the sound-track.

The optical train is self-contained, and is removable as a complete unit by unlocking two clamping screws. All adjustments are made and the unit is sealed at the factory, making the optical units interchangeable and replaceable. The ways that locate the unit and the design of the clamping screws enable positive positioning and focusing.

Optical printing from 35-mm. to 16-mm. requires the production on the 16-mm. film of an image of the 35-mm. track, moving in the same direction as the 16-mm. image and at the same speed, with a longitudinal magnification of 0.400 and a transverse magnification of 0.857. These requirements can be fulfilled only by a system containing cylindrical elements. In the present design, the proper direction of motion of the image is achieved without resorting to complicated erecting systems. Fig. 5 shows the optical layout. The negative is illuminated from inside the drum by lamp *A*, condenser *B* and prism *C*. An anastigmat lens *D* and a right-angled prism *E* form a full-size image of the moving 35-mm. track in the field lens *F*. Right-angled prism *G* and the two achromatic cylindrical components *H*, *J* form an image of this intermediate image in the 16-mm. film plane, with the proper magnification, moving in the proper direction. An area 0.063 $\times$ 0.100 is scanned on the negative. Provision is made for printing two opaque lines along the edges of the track to cut down background noise and mask the edge of the printed area.

The lamp is a photocell exciter lamp, 10-volt, 7.5 amperes, burned in a horizontal position in a water-cooled lamp house. The lamp is mounted in a special ring to assure accurate positioning of the filament.

Lamp current is supplied by a pair of 6-volt storage batteries and a full-wave charger. The charger is set to charge at approximately 115 per cent of the normal lamp current, so that the lamp power is supplied by the charger with the batteries acting as ballast to remove the 120-cycle modulation in the charger current. This arrangement and the high thermal inertia of the lamp filament provide very constant illumination. Careful tests with an 0.5-mil slit showed complete absence of 120-cycle modulation.

Lamp current is controlled by a pair of rheostats and an ammeter mounted in the control unit above the printing drums.

A signal device is provided to make it possible to make any necessary changes in exposure during printing. Notches in the edge of the negative actuate a roller contactor which signals the change point. A standard card-rack is provided for timing cards. Safety switches automatically stop the motor should the negative break. The printer is intended to be operated in a darkroom, and is equipped with the necessary safelights for convenient operation.

REFERENCES

[1] BATSEL, C. N., AND SACHTLEBEN, L. T.: "Some Characteristics of 16-Mm. Sound by Optical Reduction and Re-Recording," *J. Soc. Mot. Pict. Eng.*, **XXIV** (Feb., 1935), No. 2, p. 95.

[2] SANDVIK, O., AND STREIFFERT, J. G.: "A Continuous Optical Reduction Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XXV** (Aug., 1935), No. 2, p. 117.
[3] VICTOR, A. F.: "Continuous Optical Reduction Printing," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 96.
[4] COLLINS, M. E.: "Optical Reduction Sound Printer." *J. Soc. Mot. Pict. Eng.*, **XXVII** (July, 1936), No. 1, p. 105.

A NEW 16-MM. PROJECTOR*

H. C. WELLMAN**

The mechanism of the Model *G* Kodascope is completely housed in aluminum die castings, and is held to close tolerances both in parts and in assemblies (Figs. 1 and 2). All shafts are ground to insure straightness, finish, and size. Diameter size is held within tolerances of ±0.0002 inch. All bearings are of the oilless type, vacuum impregnated with oil shortly before assembly to give minimum wear over long periods of time. The teeth of the pull-down gears are cut after assembly to the shaft. Every assembly is checked for eccentricity, tooth spacing and finish; the allowable accumulative error in these assemblies is 0.0005 inch, and further refinement is gained by the use of an adjustable sleeve for the bearings of the pull-down shaft. The out side of the sleeve is eccentric with the bearing, so that each shaft may be adjusted for minimum backlash and correct tooth mesh of the mating gears and then locked in position. The intermittent movement consists of a tandem claw selectively hardened at points of wear, actuated by a Lumiere-type cam for the pull-down stroke, with a second cam governing the in-and-out movement. The Lumiere cam and the pull-down claw are fitted together and kept in pairs during assembly. The periphery of the Lumiere cam is ground on a special grinder used only for this purpose, the overall distance across its face being held within a tolerance of 0.0003 inch measured at any point. With this refinement and care in assembly, the operation of the mechanism is exceptionally smooth and quiet.

Threading is conventional and extremely easy. Sprocket frames open for easy access to the sprockets, and the film slides into the gate. To facilitate this operation, the *out* position of the pull-down claw is designated by a milled side on the threading knob so that its position can be noted by touch as well as by sight (Fig. 3).

Stills are shown by merely declutching the mechanism from the motor, at which time an automatic safety shutter swings into position to protect the film while the motor and fan continue to run for adequate lamp protection. By throwing a switch, the motor is reversed and pictures may be projected backwards. Framing is accomplished by shifting the pull-down claw in relation to the aperture so that there is no movement of the picture on the screen. Sprockets, sprocket

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 18, 1938.

** Eastman Kodak Co., Rochester, N. Y.

guards, film-gate, aperture plate, and pull-down claw are all designed to operate sound-film without injury.

Two features of the Model *G* deserve special mention. The first is the rewind. For rewinding, the movement of a single lever engages the rewind drive and releases the take-up reel. This lever is not only conveniently located for operation, but is so designed that it effectively obstructs the passage of film through the gate if left in the "rewind" position.

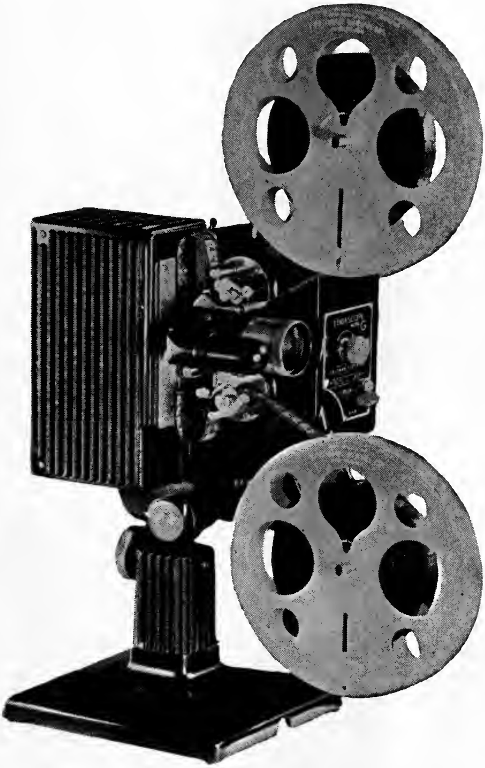

FIG. 1. The Kodascope model *G*.

Second, a single switch controls motor, threadlight, and projection lamp (Fig. 1). This switch has four positions: in the first position, motor, threadlight, and lamp are turned off; in the second position, the threadlight is turned on; in the third position, the motor is started and the threadlight remains on so that the operator can momentarily check his threading; and in the fourth position, the motor continues to run while the projection lamp is turned on and the thread-

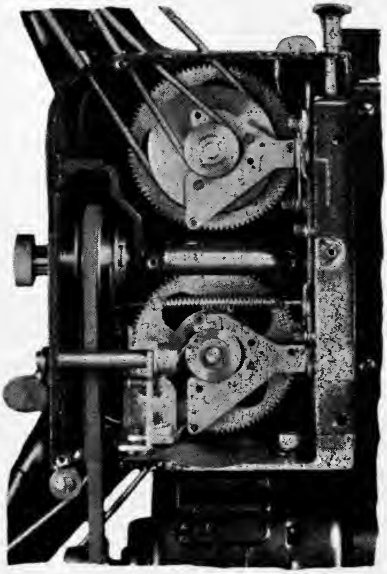

FIG. 2. The mechanism of the Kodascope Model *G*.

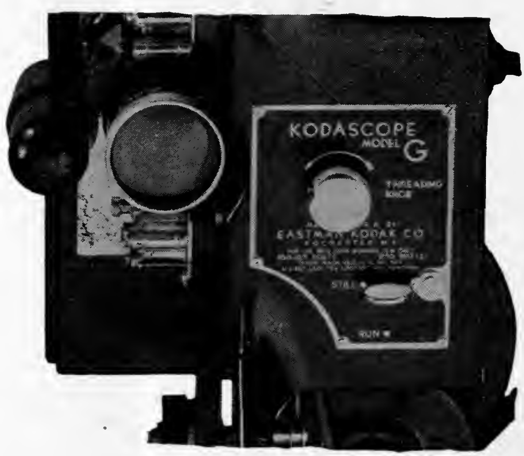

FIG. 3. Front view, showing threading knob and still picture control.

light is turned off. A single knob adjacent to this switch controls the motor speed. The threadlight is located at the side of the objective lens, and illuminates the upper and lower sprocket and the gate so that no other light is needed for changing reels in a darkened room.

The lamp house and the fan are designed to give adequate cooling for high-wattage lamps, insuring ample lamp life. The optical system was specially designed, and is remarkably efficient both as to picture quality and screen brilliance.

Elevating or tilting either upward or downward to center the picture upon the screen is accomplished by pivoting the mechanism on the pedestal base. This is controlled by an elevating knob which actuates a new elevating mechanism; it operates easily and affords a fine adjustment. Similar to the Model *EE* Kodascope, the base of the Model *G* fits over the handle of the carrying case, which may be used as a projection stand.

FIG. 4. Unit control for threadlight, motor, and lamp.

A new 2-inch, $f/1.6$ lens, especially designed for flatness of field, is standard equipment. Other lenses include a 1-inch $f/2.5$ for short throws, and either a 3-inch $f/2.0$ or a 4-inch $f/2.5$ for longer throws. These lenses, with the 400-, 500-, and 750-watt lamps permit selection from twelve possible combinations. The standard model is fitted with arms for 400-ft. reels; however, a model for 1600-ft. reels will be available. The machine is finished in hand-rubbed glossy black lacquer, with all fittings in buffed chrome plate.

A NOVEL SURGICAL FILMING STAND*

A. LENARD**

Up to now surgical filming has always been accompanied by sundry difficulties, which have often resulted in the decision not to film certain types of operations that may not have been of paramount interest or the outcome of which could not be predicted. This is easy to understand when one stops to consider all the complications and preparations necessary before undertaking to film an operation, the

* Received June 15, 1938.
** Budapest, Hungary.

many accessories and paraphernalia required in the operating room, and the tim taken to get everything ready for filming such feats. In the case of emergenc operations it has been nearly impossible to rig up the equipment in the short tim available, and it is fairly safe to say that the preparations for filming an operatio required at least half an hour before bringing in the patient.

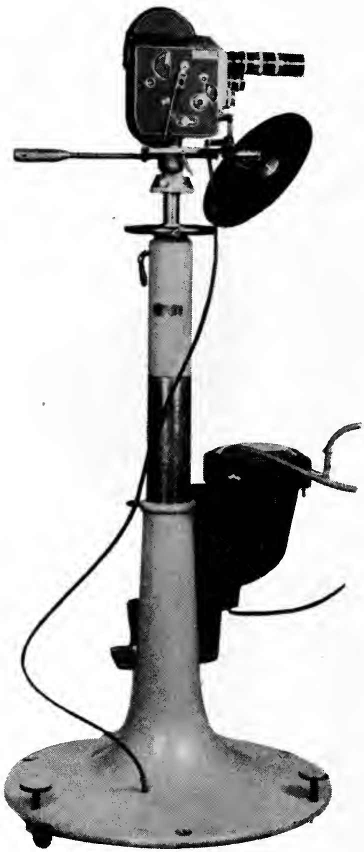

FIG. 1. General view of surgical camera stand.

Some of the difficulties generally en countered are cited below; but, in ad dition, special problems arise in almos every case that have to be solved in th shortest possible time.

It is obvious that the cameraman mus stand outside the sterile zone and wor in such a way as not to hinder th surgeon; in spite of which he nearl always wants extreme close-up shots The lighting is perhaps the "trickiest problem. Everybody who has tried t take pictures of operations knows ver well how difficult it is to place the light in such positions as to provide reall uniform illumination over the area c interest; not interfere with the surgeor assistants, and nurses; and yet be suffi ciently removed from the sterile zone Nothing must be in the way of th light-beams that will cast shadows upo the operation field and the rubber covered cables must be led along th walls so that no one may tread upo them. To accomplish all this the light have usually been placed very high necessitating the use of very high stands High stands of sufficient rigidity for us in operating rooms are not of the low priced variety. When the operation were performed within cavities, as withi the throat, ear, nose, teeth, and i gynecological and other operations, th lighting offered generally such insur mountable difficulties that as a rule suc regions were rarely if ever filmed. In these instances the light-source can be only a single unit, must be constructed s as to provide a very narrow beam, and should be positioned as near the optica axis of the taking lens as possible. The ideal condition would be realized if th beam could be made coincident with the optical axis. At the same time the bean must be able to follow, within certain limits, such pan or tilt movements of th camera as may be necessary during the shooting. Since there is only a singl beam in such cases, it must be highly concentrated; but it must not be allowed t

cause excessive heating of the tissues and consequent discomfort of the patient in cases when no anesthetic is used. A very important matter is the possibility of making quick adjustments of the camera during the operation, so that the cameraman may avoid positions from which the surgeon would obstruct the view. The ability to change cameras is very useful when the reel runs empty during an interesting phase or when the camera is spring-driven rather than electrical.

The difficulties outlined above have been eliminated effectively and by the surgical filming stand of original construction shown in Fig. 1. The stand is completely self-contained and once it is rolled into place the cameraman needs only to make the single connection to the current output and connect two rubber hoses to the water drain, which requires about ten minutes.

The base is of heavy cast iron, to provide the necessary strength and eliminate all vibration even when working at high speeds for slow-motion effects. With minute adjustments at full lens opening it is important that the camera should not move because the depth of field is then very critical. Also, when shooting small areas (teeth, *etc.*) with the telephoto lens by using extension rings under the lens and thus working from great distances, the slightest wabbling of the stand can easily spoil the macro-shot or even displace the camera sufficiently so as not to take in the required field. The total weight of the stand is about 50 kilograms. It moves on three rubber-covered rollers, and when in position is fixed by screwing three steel points down to the floor, thus obviating the slightest chance of wabble or vibration. The upright of the stand telescopes in two sections. One section provides the rough setting in height and the second (with a hand-wheel) is an accurate vernier adjustment. All adjustments can be fixed rigidly when in place. When raising or lowering the camera the lenses always point in the same direction. The lowest position of the tripod head is 85 cms., the highest 152 cms. above the ground. Thus every possible taking angle can be covered in minimum time.

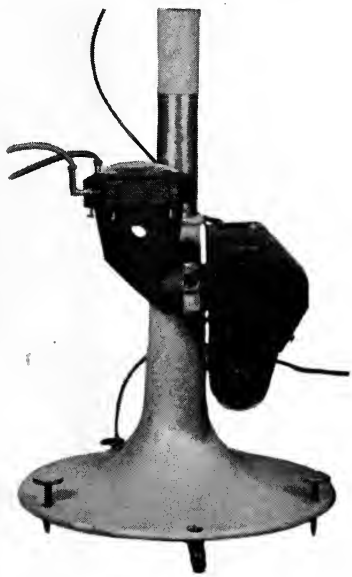

FIG. 2. Lamp house attached to base of stand, showing cooling fan and hose connection for water circulation.

A special lamp house clamped to the lower part of the stand has been developed into a medical spotlight (Fig. 2). The lamp house is positioned vertically because most projection lamps require a vertical filament position. The beam is directed through a condenser and concave mirror system to an internal plane mirror, which throws the beam upward and through a second lens system which produces the required directional spotlight effect. The lamp house is cooled by a revolving fan and the funnel-like middle piece has ample holes for ventilation. Under the

top lens is a waterholder to cool down the beam although in practice this is not really necessary, except when photographing inflamed tissues. The water can circulate through the reservoir, entering by one rubber hose and leaving by the other. The lamp is a standard 250-watt projection bulb with two plane filaments, and provides ample light for all purposes, even for slow-motion shots at 64 frames per second on supersensitive reversal material at a distance of about 2 meters from the stand with a stop of $f/2.8$.

The stand has a conventional pan and tilt tripod head for supporting the camera. A special device allows instantaneous attachment of the camera to the head by clamping, without screws, so that cameras may be changed in one second of time. Thus a loaded camera may be always held ready and put into place at

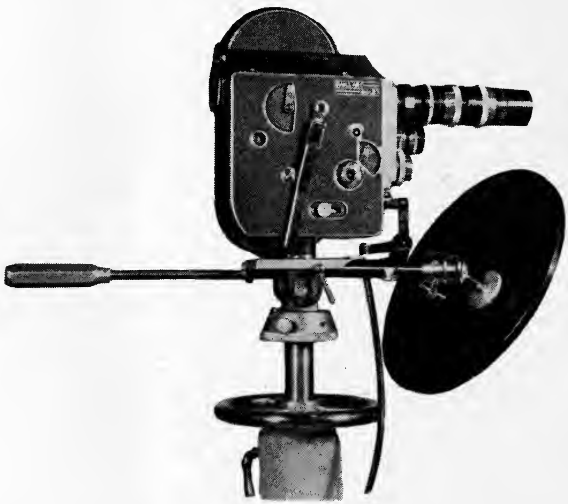

FIG. 3. Detail of camera, showing plane mirror for directing light on operation field.

the moment the one on the stand runs empty. There is always time, however, to rewind the taking camera upon the stand between phases of the operation. An electrical drive may, of course, be provided to permit shooting the full length of the 100-ft. reel, when required, without rewinding; but in practice this has never been found to be necessary, the 18-ft. run of the spring-drive having always been adequate. A wire release operated by means of a pedal allows the surgeon to make shots himself during an examination or an easy operation. Of course, he must have an assistant in any event.

The beam of the spot is directed to the operating field by a plane mirror fixed to the pan and tilt head (Fig. 3). This mirror can be moved and clamped in any desired direction by the universal ball-joint on its back. The area illuminated is checked in the view-finder, and the beam can be made fairly close to the optical axis of the lens, giving the best illumination for every purpose and the most ex-

cellent results when photographing cavities. Furthermore, as the mirror moves together with the camera when tilting or panning within reasonable limits (such as occur in work of this sort) the beam always follows the direction of the lens and illuminates the photographed area in all cases. The divergence of the beam has been calculated to have an angle of divergence of approximately 30 degrees so as to cover the field to its borders even with relatively generous angles of tilt and pan.

A Paillard Bolex 16-mm. camera was used, equipped with a special eyepiece for controlling the focus from the back. Also extension rings were used under the telephoto lens to make macro-shots from relatively great distances. The inside of the throat of a dog, for instance, filled the whole screen. The shot was made using an extension ring with a telephoto lens of 75-mm. focus from a distance of 1.5 meters.

As an example of the splendid results attained with this stand may be mentioned a slow-motion shot of vibrating vocal chords taken in the living throat Of course, the spotlight may be put out of use if not needed; for simple surgical shots two horizontal rod-holds are provided for two regular photoflood bulbs in standard reflectors on both sides of the camera. It is believed that cameramen using this stand for surgical shots will greatly enjoy the extraordinary facilities that its use makes possible.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Journal of the Acoustical Society of America

10 (July, 1938), No. 1

On Distortion in Sound Reproduction from Phonograph Records (pp. 14–28).	J. A. Pierce and F. V. Hunt
Finite Solid Acoustic Filters (pp. 41–44).	R. B. Lindsay and A. B. Focke
Acoustical Output of Air Sound Senders (pp. 50–62).	O. Devik and H. Dahl

American Cinematographer

19 (July, 1938), No. 7

Just One Camera Problem after Another Created by Speedy Sonja (pp. 268–9, 271).	J. J. Mescall
Dr. Carter Outlines History of Search for Permanent Photograph (pp. 270–1).	R. W. Carter

Journal of the British Kinematograph Society

1 (May, 1938), No. 2

Screen Brightness and its Measurement (pp. 68–89).	C. G. Heys Hallett and A.P.Casteelain
The Structure of the Industry (pp. 90–98).	S. Rowson
A Precision Instrument for the Determination of Exposure (pp. 99–119).	L. Moën
Photographic Technique for Variable-Area Recording (pp. 120–36).	S. R. Eade
A Brief Description of the British Realita Process (pp. 137–40).	

Communications

18 (July, 1938), No. 7

Notes on New Television Standards (pp. 5–8, 34).	R. F. Wild
Standard Speech-Input Assemblies (pp. 15–18, 24, 29–31).	O. Richardson
An Impedance Meter (pp. 23–4).	A. W. Barber

Electronics

11 (July, 1938), No. 7

A Laboratory Television Receiver (pp. 16–20). — D. G. FINK

Volume Indicator-Attenuator (pp. 22–4). — S. G. CARTER

A New Television Film Projector (p. 25). — H. S. BAMFORD

RMA Completes Television Standards (pp. 28–9, 55). — A. F. MURRAY

International Photographer

10 (July, 1938), No. 6

News of New Products (pp. 1–7).

Protize Process (pp. 9–10). — S. P. SOLOW

Grip Equipment (pp. 14, 16). — G. M. HAINES

Analysis of Developing Solutions (p. 22). — D. K. ALLISON

SMPE Theater Survey Report (pp. 24–7).

International Projectionist

13 (June, 1938), No. 6

Take-Up Troubles: How to Locate and Correct Them (pp. 7–8, 34). — A. C. SCHROEDER

Sound Equipment Troubles: Hum (pp. 11–12, 14). — A. NADELL

MGM Film Lubrication Policy (p. 14). — J. M. NICKOLAUS

Academy Research Council Nomenclature for Release-Print Sound-Tracks (pp. 22–24). — J. K. HILLIARD

13 (July, 1938), No. 7

Some Common Sources of Noise in Theater Sound Systems (pp. 7–8, 11, 13). — A. NADELL

Academy Recommendations on Theater Sound Reproducing Equipment (pp. 14–15, 29, 30).

Take-Up Troubles: How to Locate and Correct Them (pp. 17–19). — A. C. SCHROEDER

Kinematograph Weekly

257 (July, 1938), No. 1629

New Apparatus from Vinten Workshops: Gamma Gauge, Negative Grader, and a High-Speed Camera (p. 33). — R. HOWARD CRICKS

Kinotechnik

20 (July, 1938), No. 7

Wiedergabe tiefer Töne hoher Leistung. (High-Frequency Reproduction) (pp. 172–3). — H. BENECKE

Die Kinotechnik in der Lehrschau der Ufa (Ufa Educational Exhibit) (pp. 174–6).

Eine neue Kleinapparatur für Tonfilmaufnahme (New Small Sound Recording Camera) (pp. 176–9). — M. DIETRICH

Konstruktion von Schmalfilmprojektoren nach lichttechnischen Grundsätzen (Contruction of Substandard Projectors on the Principles of Light Optics) (pp. 179–83). — ING. M. NAGEL

Allgemeine raumakustische Betrachtungen zur elektroakustischen Schallaufnahme (General Observations on Room Acoustics for Electrical Recording) (pp. 183–6). — E. MEYER

Die Messung des photographischen Gleichrichtereffektes (Measurement of Photographic Rectifying Effect) (p. 187). — A. NARATH AND W. VOX

Neue Umkehr-Emulsionen für Schmalfilm (New Reversal Emulsions for Substandard Film) (p. 193).

Journal of the Optical Society of America

28 (July, 1938), No. 7

An Experimental Study of Latent-Image Formation by Means of Interrupted and Herschel Exposures at Low Temperatures (pp. 249–63). — J. H. WEBB AND C. H. EVANS

Philips Technical Review

3 (Apr., 1938), No. 4

The Behavior of Amplifier Valves at Very High Frequencies (pp. 103–11). — M. J. O. STRUTT AND A. VAN DER ZIEL

Photographische Industrie

36 (July 6, 1938), No. 27

Filmpflege, ihre physikalischen und chemischen Bedingungen. I. (Physical and Chemical Limitations in the Care of Film. I) (pp. 783–6). — O. TREICHEL

36 (July 13, 1938), No. 28

Filmpflege, ihre physikalischen und chemischen Bedingungen. II. (Physical and Chemical Limitations in the Care of Film. II) (pp. 807–10). — O. TREICHEL

FALL, 1938, CONVENTION

DETROIT, MICHIGAN
HOTEL STATLER
OCTOBER 31–NOVEMBER 2, INCLUSIVE

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Headquarters

The Headquarters of the Convention will be at the Hotel Statler, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, who are now engaged in preparing an excellent program of entertainment for the ladies attending the Convention.

Special hotel rates guaranteed to SMPE delegates and friends, European plan, will be as follows:

One person, room and bath	$3.00 to $6.00
Two persons, room and bath	5.00 to 8.00
Two persons (twin beds), room and bath	5.50 to 9.00
Three persons, room and bath	7.50 to 10.50
Parlor suite and bath, for one	8.50 to 11.00
Parlor suite and bath, for two	12.00 to 14.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Registrations will be made in the order in which the cards are received. Local railroad ticket agents should be consulted as regards train schedules, and rates to Detroit and return.

The following special rates have been arranged for SMPE delegates who motor to the Convention, at the National-Detroit Fireproof Garage (the Hotel Statler's official garage), Clifford and Elizabeth Streets, Detroit: Self-delivery and pick-up, 12 hours, $0.60; 24 hours, $1.00; Hotel-delivery and pick-up, 24 hours, $1.25. Special weekly rates will be available.

Technical Sessions

An attractive and interesting program of technical papers and presentations is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the Large Banquet Room of the Hotel.

Registration and Information

Registration headquarters will be located at the entrance of the Large Banquet Room, where members of the Society and guests are expected to register and receive their badges and identification cards for admittance to the sessions and film

programs. These cards will be honored also at the Fox Detroit Theater, through the courtesy of Mr. David Idzol, and special passes will be furnished to registered members and guests for admittance to the Michigan United Artists and Palms-State Theaters, through the courtesy of the United Detroit Theaters Corporation.

Informal Luncheon and Semi-Annual Banquet

The usual Informal Luncheon will be held at noon of the opening day of the Convention, October 31st, in the *Michigan Room* of the Hotel. On the evening of Tuesday, November 1st, the Semi-Annual Banquet of the Society will be held in the Grand Ballroom of the Hotel at 8 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Tours and Points of Interest

In view of the fact that this Convention will be limited to three days, no recreational program or tours have been arranged. However, arrangements may be made for visits to the Jam Handy plant and to other points of technical and general interest in Detroit on the day following the Convention, namely, November 3rd. Arrangements for such trips may be made at the registration headquarters of the Convention.

In addition to being a great industrial center, Detroit is also well known for the beauty of its parkways and buildings, and its many artistic and cultural activities. Among the important buildings that one may well visit are the Detroit Institute of Arts; the Detroit Historical Society Museum; the Russell A. Alger House, a branch of the Detroit Institute of Arts; the Cranbrook Institutions; the Shrine of the Little Flower; and the Penobscot Building.

At Greenfield Village, Dearborn, are grouped hundreds of interesting relics of early American life, and there also is located the Edison Institute, established by Henry Ford in memory of Thomas A. Edison.

On the way to Greenfield Village is the Ford Rotunda, a reception hall for visitors to the Ford Rouge Plant. Here are complete reproductions and displays of motorcar design, and representations of the famous highways of the world, from Roman days to modern, are on the grounds surrounding the building.

The General Motors Research Building and Laboratory, located on Milwaukee Avenue, will be of particular interest to engineers visiting the City.

Various trips may be taken from Detroit as a center—to Canada, by either the Ambassador Bridge or the Fleetway Tunnel; to Bloomfield Hills, a region of lakes; Canadian Lake Erie trip from Windsor, Ontario; to Flint, Michigan, another center of the automotive industry; to Milford, General Motors' Proving Grounds; and to the Thumb of Michigan Resort Beaches. The City contains also a number of beautiful parks and golf courses.

ABSTRACTS OF PAPERS OF THE FALL CONVENTION

AT

DETROIT, MICH., OCT. 31-NOV. 2, 1938

The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Fall Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

G. E. Matthews, *Chairman*
L. A. Aicholtz, *Chairman, West Coast*

P. Arnold	C. Flannagan	F. H. Richardson
C. N. Batsel	L. D. Grignon	C. R. Sawyer
L. N. Busch	E. W. Kellogg	P. R. von Schrott
O. O. Ceccarini	R. F. Mitchell	H. G. Tasker
A. A. Cook	W. A. Mueller	C. K. Wilson
L. J. J. Didiee		I. D. Wratten

"Some of the Problems Ahead in Television"; I. J. Kaar, General Electric Co. Bridgeport, Conn.

Now that television standards have been agreed upon in the United States, commercial receiving sets will undoubtedly be available very soon, and regularly scheduled television programs may be expected at the same time. How good will the television be and what are the problems yet to be solved before television reaches the technical maturity that radio has today? These are questions of considerable interest to engineers in related fields, and are the subject matter of the present paper. The quality of present-day television pictures is compared with that of motion pictures both in the theater and in the home. A discussion is given of the problems that have been solved to make television what it is today, and consideration is given to the problems that must be solved to make television what we hope it will be tomorrow. The problems of signal propagation and interference are discussed, and the matter of network program distribution is considered. Finally, a short introduction is given to the commercial problems in television.

"Some Production Aspects of Binaural Recording for Sound Motion Pictures"; W. H. Offenhauser, Jr., New York, N. Y., and J. J. Israel, Brooklyn, N. Y.

Binaural sound recording for motion pictures has a long development history of worthy achievement, yet to date it has not found application in our everyday entertainment sound motion picture. Inspection of the situation reveals that, like

stereoscopic pictures, there is not complete acceptance of any of the various theories and that the shades of interpretation are so many that it is difficult to secure a consensus on what constitutes binaural sound recording for motion pictures. Instances are cited to show that "theoretically perfect" sound is not necessarily the objective; in fact, since it is the illusion produced, both by sound and picture that is in the final analysis important, "theoretically perfect" sound may even destroy the illusion we are trying to create.

The history of binaural sound recording for motion pictures is reviewed and especial reference is made to the early developments of Rosenberg and Kuechenmeister. A short review of the developments since the work of these pioneers covers in a general way the advance of the binaural sound motion picture recording art to date. The production requirements of binaural sound recording for motion pictures are analyzed briefly and the importance of the editing process in the production of the finished picture is outlined.

A new binaural sound motion picture production technic is suggested, based upon the developments of the authors, that may be quite readily adapted to present-day monaural production technic. It is pointed out that the perspective sound control, which is an important added feature, does not affect shooting stage operations; this control is suggested as a logical part of dubbing-room operations. Some of the effects produced include variation of apparent recording-room size from very small, say, 1000 cu. ft. to very large, say, 500,000 cu. ft. Another important effect is the simultaneous yet essentially independent movement of one sound-source with respect to another and the essentially independent left-right movement. All these effects are possible with no movement whatever of the sound-source or sources with respect to the microphones. Essentially the same effects can be obtained with the pseudo-binaural system, a system in which it is possible to take a completed picture of the conventional monaural type and by a simple dubbing operation, provide practically all the important binaural characteristics without any additional original sound recording whatever. The effects described will be demonstrated.

"The Spectroheliokinematograph"; R. R. McMath, McMath-Hulbert Observatory, University of Michigan, Ann Arbor, Mich.

Taking motion pictures of celestial phenomena that show change is not as simple as it would appear at first thought. This work was started in 1928, and in 1931 the instrumentation was donated by the founders of the McMath-Hulbert Observatory to The University of Michigan.

The combined tower telescope and spectroheliokinematograph of the McMath-Hulbert Observatory at Lake Angelus, Mich., is now one of the most powerful pieces of solar apparatus in the world. The optical train will be explained by means of slides, and then the apparatus itself will be illustrated by motion pictures. A second reel will show solar prominences in motion.

"Underwater Cinematography"; E. R. F. Johnson, Mechanical Improvements Corp., Moorestown, N. J.

The dates of the first recorded use of underwater photography and the tendencies toward its increasing use by producers are noted. The author's early experiences in this field are described. The opinion is expressed that for work in natural settings the most useful equipment consists of submergeable cameras

placed on the bottom and operated by divers. The rest of the paper deals with the problems of and equipment for such work. It is pointed out that studio tank work shares most of these problems.

The optical properties of water are described. Since water is less transparent than air, photography by natural light is limited to small depths and more power is required for artificial illumination under water. Since colors are not absorbed equally, accurate monochrome rendering and photography in natural color are complicated. Water haze limits the distance at which pictures can be taken under water. This haze is largely confined to a part of the spectrum and can be eliminated partially by color-filters. It is polarized and can therefore be eliminated also by polarizing plates. The advantages of this method are briefly stated: they do not distort the monochrome rendering, and may be used in natural-color photography. The ideal attributes of equipment for use in underwater cinematography are outlined and available equipment is briefly described.

"Improving the Fidelity of Disk Records for Direct Playback"; H. J. Hasbrouck, RCA Manufacturing Co., Inc., Camden, N. J.

Recent advances in equipment design and in materials of which recording disks are composed, have resulted in improved fidelity. Both the volume range and the frequency range have been extended, satisfying present-day requirements of motion picture and broadcast applications.

For reproduction, there is provided a new lighter weight lateral pick-up having high sensitivity and equipped with a permanent diamond point. This reproducer, in combination with its associated circuit, is suitable for use on all laterial-cut disk records.

Pre- and post-equalization are employed in the method described for making high-fidelity records, insuring an extremely low noise-level. This absence of background noise together with the wide frequency range and low overall distortion create an illusion of reality or "presence" during reproduction.

Usually a great many playings are not required of direct playback disks. However, because of the low mechanical impedance of the new RCA pick-up and the improved composition of the disks it is possible to reproduce 75 to 100 times without appreciable increase in noise or distortion. Great differences in record life under various conditions of handling have been noted and are attributed chiefly to accumulation of fingerprints and dust on the record surface. Gradual oxidation of the lacquer coating must also be considered and guarded against by special care when records of this type are intended for long preservation.

"Characteristics of Film-Reproducing Systems"; F. Durst, International Projector Corp., New York, N. Y.

An analysis of sound-picture reproducing-system characteristics, including electrical and acoustical response data collected in the interest of determining the possibilities involved in obtaining an average characteristic for reproducing various film products with uniform response over several combinations of loud speaker equipment. With the aid of a curve tracer having a long-persistent cathode-ray screen, a photographic record was made of the characteristics, starting with various forms and amounts of equalization and exploring their relationship to the power-handling capacity of amplifiers. Following through the system, this record shows the characteristics of dividing networks under various conditions of

load, and finally the acoustical response curves taken for comparison of the loud speaker equipments under study.

The measurements of loud speaker combinations included various types of units, both permanent-magnet and energized, low-frequency horns ranging from open back baffles to folded horns with specially designed rear-loading compartment, and high-frequency multicellular horns of various configurations and constructional details.

After establishing the natural characteristics of the various equipments involved, careful listening tests were made over an extended period with samples of commercial prints and other recordings. A description follows of the difficulties and problems involved in an effort to obtain one overall characteristic, which would give satisfactory reproduction for all types of material. The final results are shown, with a short discussion of the methods for duplication in other equipment combinations, and conclude with recommendations for future designs and ratings.

"Some Practical Accessories for Motion Picture Recording"; R. O. Strock, Eastern Service Studios, Long Island City, N. Y.

The addition of practical operational accessories to standard recording channels as purchased expedites operation and saves time. At the Eastern Service Studios a number of such accessories have been designed and will be described briefly. It is the purpose of this paper to show what has been done at one studio in the hope that it may be of some interest and help to others who are engaged in recording work.

Included in the equipment are the following items: A small collapsible, portable microphone boom for location work; a special microphone suspension to prevent mechanical noises from getting into the recording system; a small mixer console for stage work, to permit the mixerman to operate close to the scene of action; an accurate illumination meter, using a microammeter, for setting and checking the recording machine exposure; a compact re-recording mixer console equipped with equalizers, effect filters, amplifiers, and attenuators; a projected volume indicator and footage counter for use in re-recording rooms; a film playback adapter for use on a Western Electric film machine for location use; playback horns for stage and location use; and an air-brush adaptation for blooping re-recording tracks.

"The Lighting of Theater Interiors"; F. M. Falge, General Electric Company, Cleveland, Ohio.

Here and there a theater is planned with lighting features utilizing the fundamental principles that have been expounded on many occasions. In too many cases, however, interior lighting has lagged far behind exterior lighting for advertising, and owner and public alike have suffered. In too many cases, also, the theater falls far short of complementing the attractive scenes so well projected upon the screen.

This paper reiterates the aims and advantages of proper lighting, and outlines the problem of locating, coloring, and controlling the lighting properly so that it will be comfortable and pleasing and an aid, psychologically. It discusses the possibilities of systems of lighting such as downlighting and fluorescent lighting. New materials and new light-sources will be demonstrated and discussed.

New equipment for brightness measurement will also be shown as an aid i building up a quantitative background of what conditions conduce to comfor and satisfaction.

"The Evolution of Arc Broadside Lighting Equipment"; P. Mole, Mole-Rich ardson Co., Hollywood, Calif.

From the earliest days of artificial lighting of motion picture sets the broad side type of unit has been a fundamental lighting tool. Regardless of the typ of light-source used in such lamps—whether mercury-vapor tubes, carbon arcs, o incandescent filament globes—the broadside is a lamp of the floodlight type, de signed to emit a relatively wide flood of soft, moderately powerful illumination It has withstood innumerable sweeping changes in lighting and photographi technic, including the introduction and acceptance of spotlighting, the chang from orthochromatic to panchromatic film materials, the changes from silent t talking pictures and from arc to incandescent light-sources, and the present grow ing popularity of natural-color photography.

The present paper will trace the evolution of arc broadsides only. It will com ment upon the design and performance of the early-day units, which were adapte almost intact from previous similar lamps used in photoengraving. It will follov the evolution of the broadside through successive improvements in silent-pictur usages; through its decline at the introduction of sound and Mazda lighting through the relatively recent rebirth of arc lighting due to the requirements o modern natural-color photography; and the most recently introduced units o this type which are replacing equipment designed less than five years ago at th introduction of the three-color Technicolor process. Comparison will be mad between the early, intermediate, and modern units as regards color distribution light distribution, steadiness and length of burning period, indicating that thougl less public attention has been given to these types than to the more familiar spot lighting units, the broadside has kept pace with advances in lighting and equip ment design.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

This report deals with two major projects completed by the Committee withi the past six months, namely, the third revision of the Projection Room Plans anc the proposed revision of the NFPA "Regulations for Handling Nitrocellulos Motion Picture Film." These two projects are given in detail. Other project now under consideration by the Committee are briefly mentioned.

"A Machine for Artificial Reverberation"; S. K. Wolf, Acoustic Consultants Inc., New York, N. Y.

Sometimes there arises the necessity of introducing into recorded sound a live ness that is not present in the original sound-waves impinging upon the micro phones in the recording studio. Reverberation chambers have been used to pro vide the additional liveness, but such chambers are not very flexible in use and ar costly to install.

A new machine has been developed by means of which reverberation may b introduced into the recorded sound artificially. The sound is recorded upon a endless magnetic sound-carrier or tape, which passes beneath a number of pick ups or reproducers at intervals along the carrier. These pick-ups are connecte to a mixer panel, and the sound level of each is adjusted to produce the reverber-

ant effect required. After passing the last pick-up head in the series, the sound is "wiped off" the magnetic carrier.

Such a machine finds many applications, and is useful not only in studios for direct recording, but also for adding liveness to records during the process of dubbing.

"A Silent Wind Machine for the Production Stage"; F. G. Albin, United Artists Studio Corp., Hollywood, Calif.

The machines generally used on the motion picture production set to create wind for pictorial effects are large motor-driven propeller fans mounted on floor stands. The noise level produced at high velocities is so high that satisfactory sound recording of the scene is practically impossible. Furthermore, the size and shape of these machines are such that they must be placed at such a distance that the directivity is not readily controllable. The additional hazard to sound recording of causing wind around the microphone always exists and, commonly, the desirable microphone placement is sacrificed in order to avoid the wind.

A new type of wind machine has been adopted and used for several years with a great improvement realized. The new type is a centrifugal blower, such as is commonly used in ventilating systems. The air is conducted by means of light canvas ducts from the exhaust of the blower to the set where the scene is being enacted. The ducts are equipped with variously shaped fittings and nozzles so that the air stream may be directed as desired.

It has been found expedient to locate the blower outside the stage building and enter the duct through a special portal. Thereby, the greatest noise source, the blower, is remotely located and insulated from the scene by the walls of the stage building. Furthermore, it incidentally serves as a ventilator, supplying fresh air to the scene. Measurements of noise level for various wind velocities indicate improvements up to 70 decibels in noise reduction. Thus sound recordings of scenes requiring wind are made possible where heretofore it was necessary to photograph the scene without sound and provide synchronized sound subsequently.

"Silent Variable-Speed Treadmill"; J. E. Robbins, Paramount Pictures, Inc., Hollywood, Calif.

Treadmills of various designs have been used by the motion picture industry for many years for obtaining animated shots in front of moving backgrounds. The adoption of sound practically eliminated them except for synchronized and other types of silent scenes.

This loss was keenly felt, and as a result immediate steps were taken to develop a unit that could operate throughout a wide range of speed, with fine control, instantaneous start and stop, and ability to reverse in the same shot, still maintaining a noise level that would allow the recording of intimate, quiet dialog. This was not as simple as it appeared, due to the fact that in addition to the above-mentioned requirements it also had to support the weight of two horses running, fifteen or twenty men on a march, automobiles and motorcycles in motion, *etc.* This all had to be accomplished with a unit restricted in size and weight in order to maintain mobility.

The paper discusses the problems confronting the engineering and mechanical departments throughout the design and construction of a machine that comes fairly close to doing all that was hoped for originally.

"Independent Drive for Camera in the A-c. Interlock Motor System"; F. G. Albin, United Artists Studio Corp., Hollywood, Calif.

The "Selsyn" or alternating-current interlock motor system used to drive cameras, recording, re-recording, and projection machines in synchronism, is a popular type of motor system in large studios. It has special advantages in such applications as driving projector and camera for projection background process. The one inexpedient feature is that the system is generally started from a central point such as the recording room, and the cameraman does not have means for running his camera independently as is so often required for photographing slates, exposure tests, and silent scenes.

An addition has been made to the a-c. interlock system to give it the advantages possessed by the synchronous motor system: namely, the facilities enabling the cameraman to operate his camera at will at regular speed.

The addition consists of a set of relays with control circuits, and a frequency changer and field exciter set. Normally, the camera motors are connected to the common interlock system through the relays. If, however, the button provided at the camera is depressed, the pilot relay operates and energizes the main relays which transfer the camera motor circuit to the bus of the frequency changer and field exciter set. The camera motor is operated as a true synchronous motor. One phase of the rotor is short-circuited, and the remainder is excited with direct current and serves as the field. The three-phase stator is supplied with three-phase power of a frequency that will cause the motor to run at the required speed, the same speed as when driven with the interlock system.

The power developed by the a-c. interlock camera motor when operated as a synchronous motor is approximately the same as under normal operating conditions. The acceleration is typical of small synchronous motors when the power supply is suddenly connected. The pull-in torque is superior to the slotted-rotor type of as-synchronous motor. The operation of the system is smooth, simple, and efficient, and has, after several years of use, proved its value.

"A 16-Mm. Studio Recorder"; R. W. Benfer, Electrical Research Products, Inc., New York, N. Y.

Recent advances in the commercial use of 16-mm. sound-film have stressed the importance of improving the product. Certain limitations imposed by the optical reduction process for obtaining 16-mm. sound prints are eliminated by recording 16-mm. negatives expressly for contact printing. A studio recorder for this purpose is described. The paper deals briefly with the results of considerable investigation to determine the desirable recording characteristics and concludes with a demonstration of experimental recordings.

"New Sound Recording Equipment"; D. R. Canady and V. A. Welman, Canady Sound Appliance Co., Cleveland, Ohio.

Recorder for 16-Mm. Film.—This recorder is characterized by its constancy of speed and its convenience and simplicity of operation. The constant-speed drum is not affected by temperature changes. The recorder has an aluminum magazine of 400-ft. capacity, with friction take-up and fitted for either galvanometer or glow-lamp recording, the glow lamp being preferred because of its simplicity.

Noise-Reduction Unit for Glow-Lamp Recording.—A self-contained unit, either portable or for panel mounting, which provides polarizing voltage and noise

reduction for glow-lamp recording. It has simple adjustments for setting the minimum and maximum current desired, and when these adjustments are set the unit is fully automatic. It is variable over a wide range and will give recordings from 5 to 25 ma. of current or from nearly clear negative to fully exposed negative. It has no time lag, can not react in any way with the amplifier, and may be connected to any amplifier.

Galvanometer for 35- or 16-Mm. Recording.—An oil-damped galvanometer, so designed that each of its component parts is readily adjustable, making it possible to be fitted to almost any recorder. The galvanometer has a straight-line output to 10,000 cycles.

Projector for Background Projection.—A claw projector, noiseless in operation and rock-steady, designed for the extreme requirements of background projection. The claws have three teeth on each side, the tension shoes are long, with adjustable tension, and the wear on the film is a minimum. The mechanical parts are enclosed and lubricated by an oil pump from an oil sump.

"A Color-Temperature Meter"; E. M. Lowry, Kodak Research Laboratories, Rochester, N. Y.

The recent advances in color photography have made more apparent than ever before the need for some simple and accurate method for the estimation of the color-temperature of light-sources. Photographers, whether professional or amateur, are only too well aware of the influence that the quality of the illumination has upon the color rendering of photographic subjects. For example, the difference in color-temperature between general-purpose tungsten filament lamps, and studio modeling lamps, or between modeling lamps and photoflood lamps, is often the deciding factor between correct and incorrect photographic color reproduction. In order that the photographer may easily determine the quality of the lighting he is using and make the proper adjustments to secure standard lighting conditions, an instrument that is at once compact, simple in operation, and accurate, has been developed in these laboratories. No auxiliary light-source is required for making measurements since each source is tested by means of the radiant energy that it itself emits. In this paper a discussion of the principles applied in construction of the instrument, a description of the instrument, and data showing the probable error of results are given.

"Some General Characteristics of Chromium-Nickel-Iron Alloys as Corrosion-Resisting Materials"; R. Franks, Union Carbide and Carbon Co., Inc., Niagara Falls, N. Y., and F. L. LaQue, International Nickel Co., Inc., New York, N. Y.

Those features of the chromium-nickel stainless steels are described that make these alloys useful as corrosion-resisting materials, and data are presented on the influence of the several alloying elements commonly present. It is shown how the high chemical activity of chromium benefits corrosion-resistance by reaction with oxygen or other oxidizing agents to form inert films which prevent progressive attack. The effect of chromium content upon corrosion resistance in typical reducing and oxidizing solutions is illustrated by test data.

Data are presented to illustrate the effect of nickel in achieving the desirable austenitic state, in increasing the stability of the alloys, and in supplementing the protective film-forming properties of chromium. Included in the discussion are iron-base alloys with chromium predominating, iron-base alloys with nickel

predominating, and nickel-base alloys containing high percentages of chromium. The peculiar usefulness of each type of alloy is indicated and illustrated with appropriate data.

The effect of molybdenum is treated in much the same way as the effect of nickel. The usefulness of molybdenum in improving corrosion resistance under both oxidizing and reducing conditions is pointed out, as well as its specific beneficial effects in connection with organic acids and vapors, and in reducing the susceptibility to local attack or pitting by chlorides or other halogen compounds.

There is included, also, a discussion of the effects of carbon upon corrosion-resistance with especial reference to intergranular corrosion of the austenitic alloys. Supplementing this discussion of carbon there is a description of several methods of avoiding intergranular corrosion, including the use of such stabilizing elements as columbium and titanium.

"Coördinating the Acoustical and Architectural Design of the Motion Picture Theater"; C. C. Potwin, Electrical Research Products, Inc., New York, N. Y., and B. Schlanger, New York, N. Y.

Successful design of the motion picture auditorium involves the effective coordination of both auditory and visual requirements. Past practice has favored vision and decorative treatment, usually leaving the acoustical problem as a final consideration.

In this paper a study is made of the basic outline, the volume, and the detailed form of a motion picture auditorium, to show that auditory and visual requirements can both be met successfully if they are treated with equal importance in fundamental planning. This does not preclude the ability to obtain economical design and pleasing architectural form. Actually, the study proves that economical construction and creative architectural forms are more readily inspired.

"Chemical Analysis of an MQ Developer"; R. M. Evans and W. T. Hanson, Jr., Kodak Research Laboratories, Rochester, N. Y.

The maintenance of developer activity over a long period of time is among the most important problems of a motion picture laboratory. The developer is oxidized by the silver halide in the emulsion and by air. When known amounts of these two oxidizing materials react with the developer, simple calculations, which were presented in a previous paper, are sufficient to determine the equilibrium condition of the developer as well as the replenisher formula to give a chosen equilibrium. Under ordinary conditions there are large variations in the amount of developer oxidation. A chemical analysis immediately detects any deviation from the correct equilibrium and permits readjustment of the replenisher formula. Chemical analyses are presented which require a minimum of equipment and time. In most cases, ease of manipulation and speed have been considered as more important factors than a high degree of accuracy but in all cases the methods are capable of giving results to an accuracy of five per cent or better. Whenever possible the analyses are colorimetric in nature, the measurements being made on an instrument called an Opacimeter. One operator can make a complete analysis in about half an hour. Analysis for any one constituent may be made in a much shorter time. It is emphasized that no *one* control variable is significant for specifying the activity of a developer. Sensito-

metric curves are included demonstrating the time lag in pH equilibrium but not in photographic equilibrium when hydroxide is added to or released in the developer. The aim of chemical control is to insure a constant condition of the developer and thus constant photographic quality, rather than to determine the degree of development.

"Opacimeter Used in Chemical Analysis"; R. M. Evans and G. P. Silberstein, Kodak Research Laboratories, Rochester, N. Y.

The opacimeter is an optical instrument designed to measure the light transmission of a colored or turbid solution. A Loewenthal photronic type light-sensitive cell connected to a microammeter is used to measure the intensity of the light transmitted by the solution under test. The light intensity falling upon the sensitive cell is kept within a fixed range by varying the distance of the cell from the source. The instrument is arranged so that a 30-cc. test tube or a 300-cc. Kohle flask may contain the reaction mixture. The results of analyses are determined from calibration curves prepared from known solutions.

"Some Television Problems from the Motion Picture Standpoint"; G. L. Beers, E.W. Engstrom, and I. G. Maloff, RCA Manufacturing, Co., Inc., Camden, N. J.

There are certain characteristics of television that have counterparts in motion pictures. Also, motion picture film and motion picture practice are applicable to television; some of the problems and limitations are outlined.

The following television image characteristics are briefly discussed: (*1*) number of scanning lines and the relationship to image size and viewing distance; (*2*) number of frames; (*3*) interlacing. The effect of film and optical system limitations upon reproduced television images is illustrated by photographs. Curves are given showing the spectral characteristics of Iconoscopes. The screen color characteristics of Kinescopes are discussed. The overall range and gamma characteristics of a television system are reviewed.

"Unidirectional Microphone Technic"; J. P. Livadary, Columbia Pictures Corp., Hollywood, Calif., and M. Rettinger, RCA Manufacturing Co., Inc., Los Angeles, Calif.

The paper contains a description of the construction of the unidirectional microphone, and an equation is obtained showing the cardioid directional response for this microphone.

Four definite advantages are listed for the use of this microphone in the recording of sound in motion picture studios. These advantages are (*1*) attenuation of undesirable sounds striking the microphone from the tear; (*2*) lack of frequency discrimination for sounds striking the microphone within its solid cone of reception because of the directional response of the microphone, which is practically independent of frequency; (*3*) the greater permissible microphone distance to obtain the same ratio of direct to reflected sound that exists at the position of a pressure-operated transmitter; and (*4*) the large solid angle of reception, which allows the use of fewer microphones to cover an action.

Six illustrations are given to show how this transmitter may be used to advantage under specific set conditions, and four diagrams illustrate its use for the recording of various types of music.

"A Super Sound and Picture Printer"; O. B. Depue, Burton Holmes Films, Inc., Chicago, Ill.

An improved contact printer for the continuous printing of 16-mm. sound and picture has some new film-handling features. The film may be threaded over either picture sprocket or sound printing drum or both, according as the negative is of the double- or single-film system. The picture is printed while the film is supported by a sprocket engaging the perforated edge of the film. At the same time, the other edge is supported on a roller tread and flange which, instead of being carried on the extended sprocket shaft, has its own ball-bearing mounting and is driven by the film. In this way the section of shaft is eliminated from the center of the sprocket, making possible a better location of the printing illumination beam. Thus it is possible without the addition of complicated optical elements to have the illumination fall perpendicularly upon the film at the center of the area of contact between negative and positive. The sound printing takes place similarly on a nearby drum. Provision is made at this point for the insertion of an optical filter. Lamp current is supplied by a built-in motor-generator set at any required voltage between 90 and 130.

The printer is driven through a rubber disk vibration filter. All bearings are either enclosed grease-packed ball bearings or "oilite" oilless bronze. Sprockets are made of stainless steel. The electrical system is protected by the use of an overload cut-out instead of fuses.

SOCIETY ANNOUNCEMENTS

DETROIT CONVENTION

Details of the Convention are given on page 421 of this issue of the JOURNAL. The Tentative Papers Program will be mailed to the membership of the Society about the middle of October. Members who plan to attend the Convention are urged to return their hotel reservation cards as promptly as possible in order to be assured of satisfactory accommodations.

PROJECTION PRACTICE COMMITTEE

Several meetings of the Sub-Committee on Projection Room Plans were held during the summer, the last one being on September 9th, at the office of the Society. The result of this work was the completion of the third revision of the Projection Room Plans, which, together with the proposed revision of the NFPA "Regulations for Handling Nitrocellulose Film," completed by the Committee several months ago, will form the report of the Projection Practice Committee to be presented at the Detroit Convention.

A meeting of the entire Committee was held on September 15th to edit a preliminary draft of the report, and another meeting will be held on October 13th to approve the final draft.

MID-WEST SECTION

On Thursday, September 20th, at the meeting rooms of The Western Society of Engineers, the Mid-West Section of the Society held its first meeting of the season. Mr. Richard Leitner of the Gumbiner Syncro-Sound, Inc., of Los Angeles presented a paper describing " A Professional 16-Mm. Sound-on-Film Camera."

The meeting was well attended and an interesting discussion followed the presentation.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

BAMFORD, H. S.
485 California St.,
San Francisco, Calif.

BAUMBACH, H. L.
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CROWLEY, W. G.
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DEFARIA, A.
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HENDERSON, F. J.
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KAUSER, J.
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MIATT, R. W.
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NAVARRO, R. F.
Parlatone Hispano Filipino,
Motion Picture Co.,
Manila, P. I.

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138—28th St.,
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PETERSON, S.
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SARBER, H.
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P. O. Box 263,
Syosset, N. Y.

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1868–1938

Professor Norman McClintock, distinguished photo-naturalist and member of the Society, died of a heart attack at Orlando, Florida, on February 26, 1938. Professor McClintock joined the staff of Rutgers University at New Brunswick, N. J., in 1931 as a special lecturer, and retained the position to the time of his death.

Norman McClintock received his B.A. degree from Yale University in 1891. He became interested actively in motion picture photography of insect life, plant life, wild birds, and big game about 1914. For nearly a quarter of a century he devoted his full time to these studies, and was one of the first to make fine quality motion picture studies of bird and plant life. His services as a lecturer were much in demand because of the remarkable films which he showed and the unusual personality of the speaker.

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JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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ELECTRICAL NETWORKS FOR SOUND RECORDING*

F. L. HOPPER**

Summary.—*Electrical networks are employed in sound recording for modifying and limiting the frequency-response characteristic. The necessity for their use, application, and design is described. Particular emphasis is placed upon the constant-resistance type of structure.*

The design philosophy for a transmission system to translate the spoken word or music into some form of record has been one predicated upon the use of elements having uniform response-frequency characteristics. In sound recording a number of factors exist that necessitate certain modification and limitation of these characteristics in order to achieve pleasing results. Some of these factors are:

(*a*) The effects due to the acoustical conditions surrounding the point of pick-up.
(*b*) The response characteristic of the microphone.
(*c*) The properties of the modulating device and noise-reduction system.
(*d*) In re-recording, the ability to compensate for defects occurring in recording, and the introduction of characteristics providing certain dramatic effects.

All these alterations of characteristic are accomplished by the use of various passive electrical networks. Those employed for modification make use of the properties of resonant circuits, combinations of capacity or inductance with resistance, or the grouping of such elements into the lattice or bridged-*T* type of constant-resistance network.

Limitation of the frequency-response characteristic is accomplished by grouping inductance and capacity elements into high- and low-pass filter structures. Occasionally, constant-resistance networks, alone or in combination with filter sections, are used.

The choice of a particular type of network depends upon the required insertion loss, the impedance of the circuit in which it is to operate, and the reaction of the network's impedance characteristic

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 18, 1938.

** Electrical Research Products, Inc., Hollywood, Calif.

upon the frequency-response of the equipment associated with it. The last factor is of considerable importance when a network is connected to the input circuit of an amplifier, since frequently the amplifier response is altered when working into an incorrect or varying impedance. A comparable condition may exist when a network is operated on the output of an amplifier, particularly if the amplifier output stage contains pentodes. In addition, if a number of networks are to be connected in tandem, the constant-resistance type is advisable. Generally, one end of a constant-resistance structure must be terminated ideally if terminal effects are to be made negligible. Several constant-resistance networks in tandem will add their respective loss characteristics without interaction provided they are designed for the same nominal terminating resistance, and are actually terminated in this resistance at one end. If neither end is well terminated, or if some non-constant resistance network is included in the chain, the overall loss characteristic will show interaction effects. The generally desirable features of networks of this type have resulted in their nearly universal use for modifying the characteristic in sound recording.

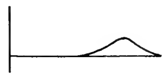
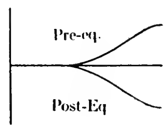
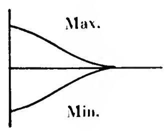
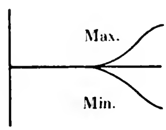
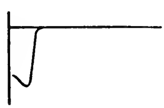
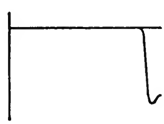
These same criteria apply to the choice of filter structures for limiting the frequency-response characteristic. Usually the filter is composed of combinations of constant-K and M-derived sections, since the constant-resistance network does not usually introduce insertion loss with sufficient rapidity. A number of the commonly used types of networks, their functions, types of service, and characteristics are given in Table I.

The networks shown by no means constitute a complete list, but may be regarded as representative of those in use in many of the studios. Among other types having more limited use are those for equalizing monitoring systems and a number of special types employed in re-recording, which permit attenuating certain restricted bands of frequencies to achieve special effects.

The designs of filters used for limiting the frequency-response characteristic are well covered in the literature.[1] Design data pertaining to the constant-resistance type of network are probably not so well known.

Since this structure has so many applications in the recording field, it is of interest to consider its design. We may choose the bridged-T form, since nearly all transmission circuits wherein such equalizers are employed are grounded on one side. In addition, this type re-

TABLE I

Network	*Function*	*Service*	*Response*
Dialog Equalizer	Compensates for stage conditions.	Recording	
Microphone Equalizer	Compensates for microphone irregularities or certain acoustical response effects.	Recording	Depends upon microphones used
Presence Equalizer	Corrects for certain Acoustic Pick-up Effects.	Recording	
Pre-Equalizer Post-Equalizer	Increases highs subsequently attenuated in reproducing. Used to reduce noise.	Recording and Reproducing	
Film Equalizer	Compensates for film losses.	Re-recording	
Low-Frequency Corrective	Permits adjustment of response for corrective or dramatic effects.	Re-recording	
High-Frequency Corrective	Permits adjustment of response for corrective or dramatic effects.	Re-recording	
High-Pass Filter	Limits low-frequency response.	Recording and Re-recording	
Low-Pass Filter	Limits high-frequency response, depending partially upon modulating devices characteristic.	Recording and Re-recording	

quires fewer elements than the lattice structure. The general form of the network is shown in Fig. 1. The resistances A, A, and B form a conventional T type of "pad." This may be of either the finite or infinite loss type, depending upon the design problem. The element Z_{11} is arbitrarily chosen as the independent variable determining the transmission characteristic of the network. The elements comprising Z_{11} may be reactive, resistive, or a combination of both. Networks used in sound recording usually employ elements consisting essentially of pure reactance. Consequently, this case will be considered first.

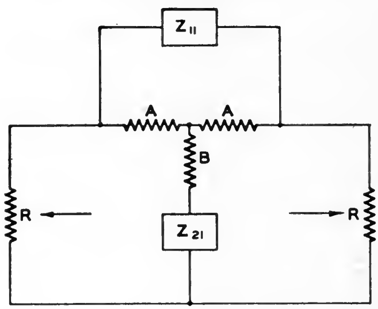


FIG. 1. Simple bridged-T network: $A = A = R/c$; $B = (C^2-1)R/2C$.

The factors determining the insertion loss, in decibels, of a given network are:

(*a*) The loss of the T pad.
(*b*) The impedance of the reactive element Z_{11}.
(*c*) The iterative impedance, R, of the circuit in which the network is to operate.

An equation relating these quantities is derived in the appendix of this paper. In Fig. 2, a family of curves representing various pad losses has been plotted as a function of the impedance Z_{11} as abscissa, and the corresponding network insertion losses as ordinates. R is assumed to be 500 ohms. The relations between Z_{11} and Z_{21}, their use as elements in various networks, and the characteristics of such networks are shown in Fig. 3.

In the design of a particular network Fig. 3 enables a choice of element Z_{11} to effect a certain shape of characteristic. If the required characteristic is somewhat complex, it may be necessary to achieve the final desired characteristic by employing one or more networks, the sum of their individual characteristics resulting in the required one. In addition, the following data are necessary:

(*a*) The maximum required insertion loss, determining the pad value.
(*b*) The insertion loss at some particular frequency which effectively determines the shape of the insertion loss characteristic. This in turn determines the value of Z_{11} (from Fig. 2) and from Fig. 3 the values of the reactive elements L and

C may be computed. From these, the impedance Z_{11} may be computed for other frequencies and the insertion loss read from the charts of Fig. 2.

An example of such a computation is given in the appendix.

It is apparent from an inspection of Fig. 2 that the insertion loss approaches the pad loss for large values of the impedance Z_{11}, and hence does not become infinite. If the T pad is of the infinite-loss

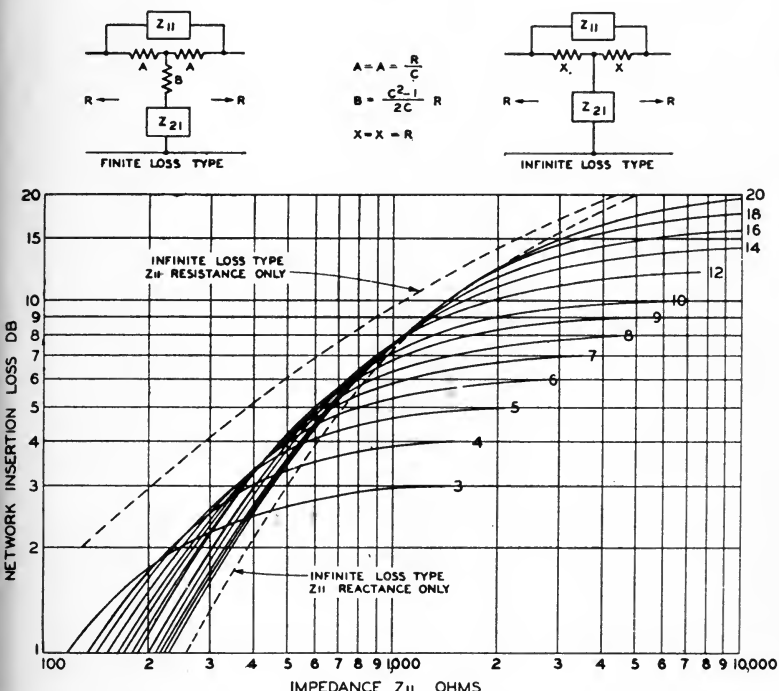


FIG. 2. Constant-resistance network design chart (curves give insertion loss in a 500-ohm circuit).

type, *i. e.*, if $A = A = R$ and B is zero, the insertion loss of the network becomes increasingly large as Z_{11} increases, approaching infinity as Z_{11} approaches infinity and Z_{21} approaches zero. A design curve for this type of structure is included in Fig. 2.

Another special condition having practical use in the design of variable attenuators is the case when Z_{11} is resistance only. This affords the opportunity of designing a bridged-T type of attenuator

having constant-resistance properties. Design information for this case is also presented in Fig. 2.

Phase-shift introduced into a circuit by the resistance-arm bridged-*T* structure shown in Fig. 1 will usually be less than 40 degrees for

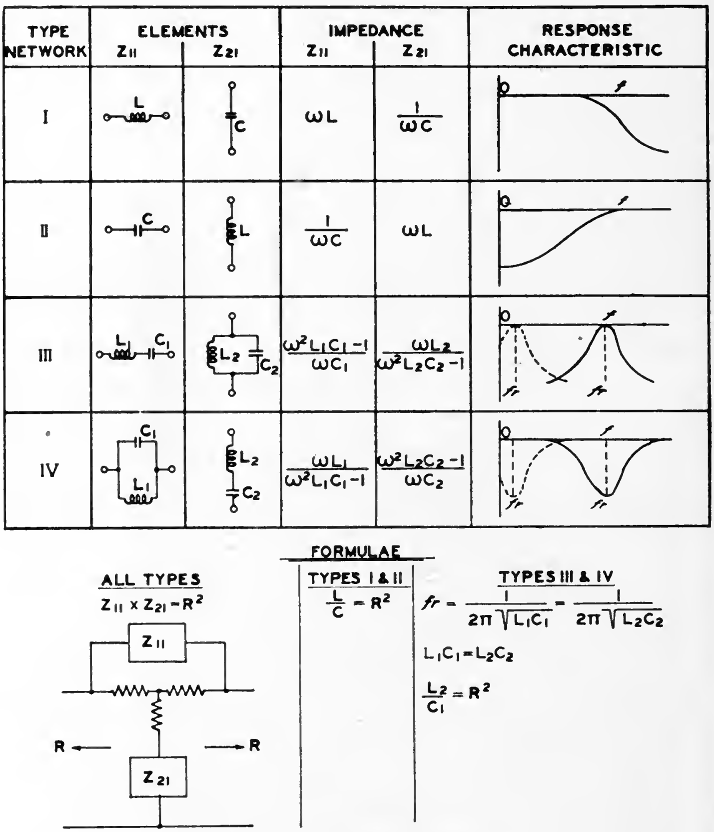


FIG. 3. Equalizer chart.

networks employing finite pads, and will approach 90 degrees as a maximum for networks employing an infinite-loss type of pad.

The wide adaptability of constant-resistance networks to the equalization requirements of sound recording is best demonstrated by their wide-spread use. The methods outlined here simplify the design of such networks to meet specific characteristics.

APPENDIX

Referring to Fig. 1, the general form of the bridged-T network, the resistances R/c, R/c, and $(c^2 - 1)R/2c$ form a conventional T type of pad. The value of c for a given pad loss is given by

$$\text{Pad loss in db.} = 20 \log \frac{i_1}{i_2} = 20 \log_{10} n \tag{1}$$

where i_1 = current in the load resistance when the pad is not in the circuit.
i_2 = current in the load resistance when the pad is inserted in the circuit.

c is then defined as

$$c = \frac{n+1}{n-1} \tag{2}$$

For the network, Z_{11} is arbitrarily taken as the independent variable determining the propagation constant. Z_{21} is dependent upon Z_{11} through the relation

$$Z_{11} \times Z_{21} = R^2 \tag{3}$$

The propagation constant of the network is given by Zobel[2] as:

$$e^{\Gamma} = \frac{1 + \dfrac{(c+1)}{2}\dfrac{Z_{11}}{R}}{1 + \dfrac{(c-1)}{2}\dfrac{Z_{11}}{R}} \tag{4}$$

From eq. *4* both the attenuation and phase constants may be obtained since

$$e^{\Gamma} = e^{\alpha + j\beta} = m + jn \tag{5}$$

and

$$e^{\alpha} = \sqrt{m^2 + n^2} \tag{6}$$

where α is the attenuation constant in napiers.
The phase constant β in degrees is given by

$$\tan \beta = \frac{n}{m} \tag{7}$$

A general solution of eq. *4*, assuming that Z_{11} is composed of both reactance and resistance gives

$$Z_{11} = \frac{-r}{s} \cos\theta\, R \pm R \sqrt{\left(\frac{r}{s}\cos\theta\right)^2 + \frac{e^{2\alpha} - 1}{s}} \tag{8}$$

where

$$r = \left(\frac{c+1}{2}\right) - \left(\frac{c-1}{2}\right) e^{2\alpha}$$

$$s = \left(\frac{c+1}{2}\right)^2 - \left(\frac{c-1}{2}\right)^2 e^{2\alpha}$$

θ = angle between the resistance and reactance components of Z_{11}. For the

case when Z_{11} is reactance only eq. *8* may be simplified, since θ is 90 degrees an cos $\theta = 0$. Eq. *8* then becomes

$$Z_{11} = R\sqrt{\frac{e^{2\alpha} - 1}{\left(\frac{c+1}{2}\right)^2 - \left(\frac{c-1}{2}\right)^2 e^{2\alpha}}} \qquad (9)$$

Eq. *9* may be simplified for direct substitution by converting the attenuatio in napiers to attenuation in decibels, resulting in

$$Z_{11} = R\sqrt{\frac{e^{0.23db.} - 1}{\left(\frac{c+1}{2}\right)^2 - \left(\frac{c-1}{2}\right)^2 e^{0.23db.}}} \qquad (10)$$

where $db.$ = the insertion loss of the network.

Z_{11} = impedance in ohms of the reactive element of the network.

Eq. *10* has been plotted for design purposes assuming R is 500 ohms in Fig. 2

For the infinite-loss type of pad $c = 1$, and the pad resistances become $A =$ $A = R$, and $B = 0$. Substituting $c = 1$ in eq. *10* gives

$$Z_{11} = R\sqrt{e^{2\alpha} - 1} \qquad (11)$$

This is plotted in Fig. 2, assuming R to be 500 ohms.

Referring to eq. *8*, if no reactance is involved but only resistance, θ is zero de grees, and $\cos\theta = 1$; hence

$$Z_{11} = \frac{-r}{s}R \pm R\sqrt{\left(\frac{r}{s}\right)^2 + \frac{e^{2\alpha} - 1}{s}} \qquad (12)$$

For an infinite-loss type of pad $c = 1$, $r = s = 1$ and eq. *12* becomes

$$Z_{11} = R(e^{\alpha} - 1) \qquad (13)$$

This equation permits the design of a bridged-T type of attenuator having con stant-resistance properties. It has been plotted in Fig. 2.

The phase change introduced by a network employing a finite pad may be com puted from eq. *7*, and, for the case where Z_{11} is reactance only, becomes

$$\beta = \tan^{-1}\frac{\frac{Z_{11}}{R}}{1 + \frac{c^2 - 1}{4}\left(\frac{Z_{11}}{R}\right)^2} \qquad (14)$$

Examples of the use of this design data follow.

Low-Frequency Attenuating Network.—Assume that the requirements for thi network are an insertion loss of 4 db. at 100 cycles, and about 8 db. at 20 cycles when connected in a 500-ohm circuit. Reference to Fig. 3 indicates that Z_1 should be a capacity C, and Z_{21} an inductance L. Since the maximum require loss is 8 db., a pad of that value is chosen. The insertion loss at 100 cycles deter

mines the value of Z_{11} or C as follows: From Fig. 2 for an 8-db. pad and 4-db. insertion loss Z_{11} is 490 ohms. Since $Z_{11} = 1/\omega C$ and ω at 100 cycles is $2\pi \times 100$ we have

$$C = \frac{1}{\omega Z_{11}} = \frac{1}{628 \times 490} = 3.24 \text{ mfd.}$$

and

$$L = R^2C = 500^2 \times 3.24 \times 10^{-6} = 0.81\ h$$

Having determined these constants the insertion loss at other frequencies may be found as follows:

Freq.	ω	ωC	$\frac{1}{\omega C} = Z_{11}$	Ins. Loss (Fig. 2)
20	125	407×10^{-6}	2460	7.6 db.
40	252	817	1220	6.8
100	628	2030	490	4.0
200	1256	4060	246	1.7

Equalizer for Re-Recording System to Simulate Poor Radio Quality.—Assume that the requirements for this network are no insertion loss at 800 cycles, 7 db. at 300 cycles, and with increasing insertion losses at both extreme low and high frequencies. The network is to operate in a 500-ohm circuit. Fig. 3 indicates the choice of a series-resonant circuit comprised of L_1 and C_1 for Z_{11}, and an anti-resonant circuit composed of L_2 and C_2 for Z_{21}. Since the network losses are to increase outside the specified limits, an infinite-loss type of pad is used. The values of L_1, C_1 are determined from the insertion loss requirement of 7 db. at 300 cycles as follows:

Since f_r occurs at 800 cycles, the frequency for no insertion loss,

$$f_r = \frac{1}{2\pi\sqrt{L_1C_1}} \text{ or } L_1C_1 = \frac{1}{4\pi^2 \times 800^2} = 4 \times 10^{-8}$$

and Z_{11} for a 7-db. insertion loss with an infinite-loss pad (from Fig. 2) is 990 ohms.

$$Z_{11} = \frac{\omega^2 L_1 C_1 - 1}{\omega C_1} \text{ or } C_1 = \frac{\omega^2 L_1 C_1 - 1}{\omega Z_{11}}$$

$$= \frac{(2\pi \times 300)^2 \times 4 \times 10^{-8} - 1}{2\pi \times 300 \times 990} = 0.464 \text{ mfd.}$$

and

$$L_1 = \frac{4 \times 10^{-8}}{0.464 \times 10^{-6}} = 0.0865 \text{ h.}$$

$$L_2 = C_1R^2 = 0.464 \times 10^{-6} \times 500^2 = 0.116 \text{ h.}$$

and

$$C_2 = \frac{4 \times 10^{-8}}{0.116} = 0.345 \text{ mfd.}$$

Insertion losses at other frequencies are:

Freq.	ω	ω^2	$\omega^2 L_1 C_1$	$\omega^2 L_1 C_1 - 1$	ωC_1	Z_{11}	Ins. Loss (Fig. 2)
100	628	0.39×10^6	0.0155	0.985	0.000291	3380	16.8 db.
300	1,880	3.51	0.14	0.86	0.00087	990	7.0
500	3,140	9.8	0.39	0.61	0.00145	420	2.3
800	5,020	26	1.0	0	0.00233	0	0
1000	6,280	39	1.56	0.56	0.0029	193	>1.0
2000	12,560	157	6.28	5.28	0.00581	910	6.5
3000	18,800	352	14.1	13.1	0.0087	1510	10.0

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[1] SHEA, T. E.: "Transmission Networks and Wave-Filters," D. Van N strand Co. (New York).

[2] ZOBEL, O. J.: "Distortion Correction in Electrical Circuits," *Bell. Sy Tech. J.*, **VII** (July, 1928), No. 7, p. 438.

A NON-INTERMITTENT PROJECTOR FOR TELEVISION FILM TRANSMISSION*

H. S. BAMFORD**

Summary.—*A continuous machine is described for the projection of images from lm into the pick-up camera for television transmission of motion pictures. The ımera tube can be either of the instantaneous or the storage type. The images are ıcident upon the cathode during scansion and the optical image transition interval ; less than the scanning flyback interval with which it is synchronized. Certain adıntages are taken in the construction of a double-lens disk type of optical compensator › obtain an image steadiness determined only by the number of lenses per disk, such ·rors as are introduced by lens setting and gearing being negligible.*

The telecine projector to be described operates upon the principle f optical compensation as the film moves continuously through the lm gate and can, therefore, be called a continuous or non-interıittent type of machine. As a telecine projector, it is applicable trictly to the projection of images from film for television pick-up, nd the images so projected are substantially stationary.

Fig. 1 is a photograph of such a machine, constructed to project :om 35-mm. sound recorded film, and similarly the principle of peration can be applied to 16-mm. sound-film projection when the umber of images per second is 24.

The machine is operable with a pick-up tube of either the intantaneous or the storage type. By instantaneous type of pick-up ıbe is meant a tube wherein the elemental signal leaving the tube is epresentative of the optical image element at the instant it is scanned, nd is of an intensity determined by the light-intensity, sensitivity f the cathode surface, the element area, and the time required to :an the element area. Obviously, the absence of an optical image pon the cathode during the whole or part of the scansion interval esults in either a total blank or an image with a horizontal blank bar ıe width of the image, and of a height determined by the interval of ptical image cut-off.

* Received July 1, 1938.

** Farnsworth Television, Inc., Philadelphia, Pa.

A pick-up tube of the storage type is one in which the optical image incident upon the cathode gives rise to a charge image which remains until it is removed by scansion, and the resulting elemental signal leaving the tube is representative of the elemental charge stored upon the cathode during optical image incidence of an intensity determined by the intensity of the light, sensitivity of the cathode surface, the element area, the time required to completely scan one frame, and a factor, K.

The Farnsworth "dissector" is an example of the instantaneous type of pick-up tube; the iconoscope, emitron, and image amplifier, examples of the storage type.

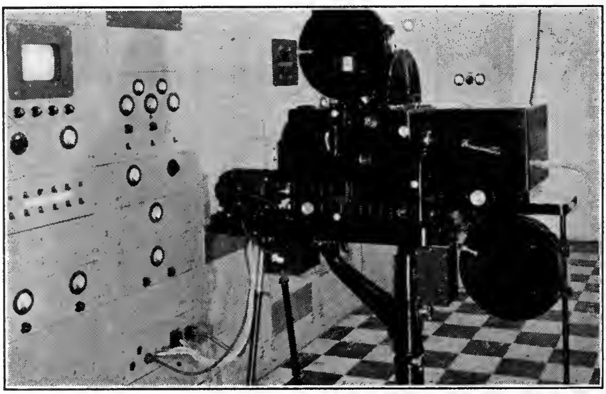

FIG. 1. Telecine projector.

Such a universal application can be better understood and certain advantages recognized when we consider that the projected image is stationary upon the cathode of the pick-up device and has a duration equal to the scanning time, changes from image to image occurring only during the scanning flyback interval. According to present standards, the time allowed for flyback between scansions is 10 per cent of the field scansion time, or $^1/_{600}$ second. Such a requirement should make obvious the need for a machine of the continuous type in which optical image transition can be accomplished at very high speed as compared with the intermittent type projector, wherein the optical image transition time is limited to a speed determined by the ability of the film to withstand the effect of the acceleration with increasing tension necessary at the film gate to maintain steadiness.

A 72-degree intermittent jerking the film into its successive positions in $^1/_{120}$ second is by no means a slow intermittent movement. In addition, various methods of selection of optical image sequence can be simply accommodated, including the method wherein successive images are superimposed for a brief transition interval, during which interval the total light is kept constant by the selector disk.

Many systems of optical compensation have been designed and tried in the past for theater projection, using lenses, prisms, or mirrors, and many more systems can be conceived, using them in combination, giving almost perfect first-order results. However, the first-order derivation is not sufficient to predict the overall performance of the system. The presence of third-order aberrations in sufficient magnitude will destroy what might look to be a perfect

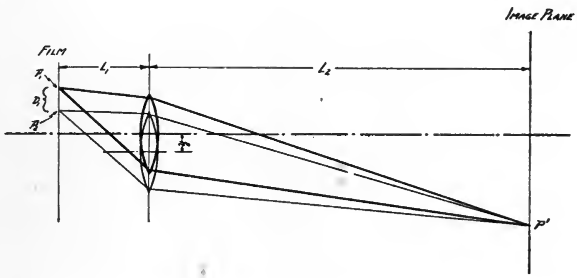

FIG. 2. Illustrating method of optical compensation.

design. In addition, the physical setting of the component elements and the mechanical drive of the system are obviously of extreme importance. The effects upon the projected optical image by a machine in which these faults are present are unsteadiness during image incidence and lack of coincidence of successive image frames. Both in effect constitute image jump, and their effects are more destructive in telecine projection due to the present system of interlacing than they would be for direct viewing or non-interlaced scanning.

Some systems lend themselves admirably to the fulfillment of the above-described requirements, while others do not. It is not possible in a limited space, nor would it be of general interest, to discuss in detail various systems of optical compensation and their qualities and failings, though it might be well to inject some general considerations. A system in which the optical compensator is a single unit is going to require that the driving gear be extremely accurate;

many times more accurate than the pair of gears required to drive the optical compensator of the symmetrical double-unit type. That the optical elements can be corrected with no great difficulty, if at all, is another consideration. The following is intended to indicate an approach to the ideal optical compensator for the particular purpose outlined.

Fig. 2 illustrates a method of optical compensation wherein the motion of a lens is made to compensate for film motion, so that the projected image is stationary, and equation *1* gives these required motion relationships:

$$d_1 = -y\,(1/m - 1) \qquad (1)$$

d_1 = film displacement.
y = lens displacement.
m = magnification.

Equal numbers of lenses mounted upon two oppositely rotating disks in optical mesh can be made to constitute a succession of well corrected projection objectives of very closely matched focal length and magnification. By optical mesh is meant that each lens on the one disk overlaps a lens on the other, so that they form substantially a symmetrical objective. As the disks rotate through the necessary angle, the component lenses move apart in equal amounts in opposite directions, and by selecting a slightly different focal length for the one disk the effects of these horizontal displacements upon the projected image are mutually annulled.

Two components of a composite lens contribute to the total magnification of the system in amounts:

$$m_1 = \frac{m\,(f_1 + f_2 - a)}{mf_1 + f_2} \qquad (2)$$

$$m_2 = \frac{m\,f_1 + f_2}{f_1 + f_2 - a} \qquad (3)$$

f_1 = focal length of the first lens.
f_2 = focal length of the second lens.
m_1 = magnification by the first lens.
m_2 = magnification by the second lens.
a = separation of the component lenses.

The displacement of an image point by the displacement of a lens is:

$$x = y\,(1 - m) \qquad (4)$$

$m = m_1m_2$ = magnification of the system.

Therefore, for complete annullment of the horizontal displacements

of the two component lenses, the focal lengths must be related as follows:

$$f_1 = f_2 - \frac{a\,(m+1)}{m-1} \tag{5}$$

Should the focal lengths of the two component lenses be the same, $f_1 = f_2$, the horizontal displacement error can be computed from equation *6*, wherein $y_1 = -y_2$:

$$E_H = \frac{y_1\,a\,(m+1)}{2f_1 - a} \tag{6}$$

E_H = horizontal displacement error.
y_1 = horizontal displacement of lens No. 1.
y_2 = horizontal displacement of lens No. 2.

Substitution in equation *6*, for the particular system used, will indicate a negligible value of E_H when the focal length of the lens on the front disk is similar to that of the lens on the rear, with consequent advantages in construction.

The vertical component of the lens motion is parallel to the motion of the film and constitutes to an acceptable degree the compensating motion, y, as set forth in equation *1*. This vertical motion of the lens varies as the sine of the angle of rotation of the disks and is, therefore, nonuniform, while the film is moved through a plane gate at a uniform rate. Obviously, the projected image will not be perfectly stationary, but will be periodically displaced vertically a small amount, such amount being termed the vertical displacement error. This vertical displacement error contributes to the overall image jump. By the proper selection of the lens disk radius, a minimum vertical displacement error can be derived for a given magnification and angular projection interval of the disks. The number of lenses per disk determines the angular projection interval, while the number selected is determined by the allowable vertical displacement error, and the allowable horizontal separation of the overlapped component lenses.

The use of a curved film gate in allowing an average correction of the lens disk sine error introduces a displacement error by virtue of its distorting effect. Defocusing also results when the image is projected from film running through a curved gate onto a plane. Obviously, lens curvature can only make an average correction for gate curvature, while curvature of the cathode must include consideration of the electron optical system.

In consideration of the following, the diameters of the lenses are such that only the required amount of light is projected, and not a needless excess; and the system magnification, determined by the lens disk radius, is such that the projected image needs little modification by a fixed-axis auxiliary lens. The third-order aberrations all vary as some function of the lens aperture. The magnification of the lens disk gear errors is proportional to the ratio of the lens disk diameter to the pitch diameter of the gear. Still more reasons can be cited to indicate the importance of the correct determination of the lens aperture; the reasons given above are obviously most important.

The mounting of the lenses upon the disks in their correct positions is made possible to a reasonably high degree of precision by virtue of the fineness of lens correction and uniformity. The grinding, centering, and edging of the component elements must be well done and a reasonable uniformity maintained in element thicknesses. A high degree of uniformity of focal length is facilitated by the ability to modify slightly when cementing the component elements. The cemented achromat is mounted in a holder, preferably of the same metal as the disks, and gripped so that there will be no strain. Slipping after the settings are made, either of the holder on the disk or the lens in the holder, must not occur. It is not abnormally difficult to mount these lenses in their holders upon the disks spaced from each other and similar in radii to within 0.0002 inch. As the effect upon the projected image is divided between the two overlapped lenses—equations *2*, *3*, and *4*—and each lens has its own setting error not exceeding 0.0002 inch, the image displacement will be some average not exceeding $0.0002(1-m)$ inch, or possibly zero when the setting errors of the two lenses are equal and opposite. A detailed description of the alignment procedure is impossible in a limited space; it is sufficient to say that the order of accuracy involves in the aligning instrument a good degree of thermal and mechanical stability.

The lens disks are geared directly to the film drive sprocket shaft so that the errors due to nonuniformity of drive are not present in the projected image. The gear train from the film drive sprocket to the lens disks is so designed that annullment of eccentric error is accomplished to a high degree and the transmission of residual errors is reduced in proportion to the ratio of the pitch diameters of the common shaft gears. The four gears driving the two lens disks can be so arranged that their eccentric errors are subtractive by virtue of the optical mesh. Such advantages of gear arrangement can not be

taken in most other systems with consequent requirements of almost impossible precision in gear cutting and attendant high cost. The gears are bronze mating with steel cut on a gear shaper and enveloped to give what might be called a commercial high-precision gear. Enveloping, or shaving, as it is sometimes called, is very effective in finishing a well cut gear so as to correct eccentricity, nonuniformity of tooth spacing, and involute profile, beside smoothly finishing the

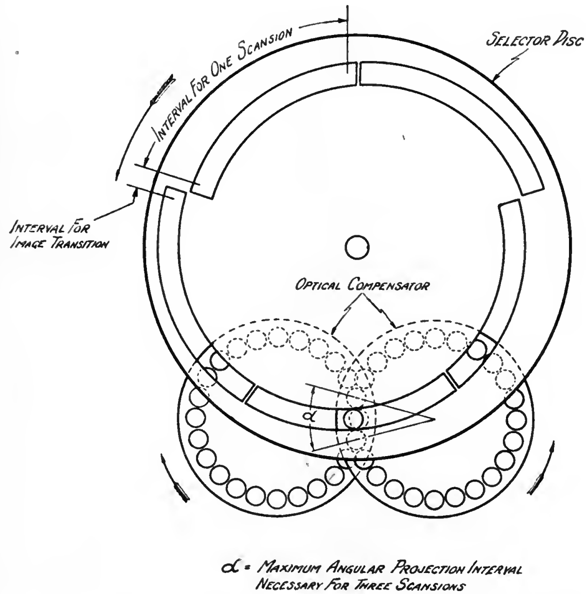

FIG. 3. Selection disk in relation to lens disks.

tooth faces. This smooth finish has much to do with maintaining accuracy over a period of time.

The driving of the film through the film gate constitutes another problem to which attention must be given. Due to the fact that the image is projected while the film is moving, variations in that motion naturally result in an unsteady image. If the film is pulled through the gate by a sprocket, and the sprocket teeth do not accurately match the film perforations, periodic slipping of the film will result at a frequency of 96 per second, for 35-mm. film. Obviously, the images projected from a film so driven will have a periodic vertical jump. Variation in shrinkage of films according to their age and

treatment makes it impossible to determine a fixed sprocket size that will give acceptable results. A sprocket with a variable diameter, graduated, will accommodate different films and was tried experimentally with considerable success. That the shrinkage is sufficiently uniform throughout the reel to satisfy present requirements for a given setting has been indicated in the results so far obtained. Framing the film in the gate is very simply done with the sprocket drive method by increasing or decreasing a loop between the gate and the film drive sprocket with a displaceable idling roller.

The images are projected upon the cathode of the pick-up tube in correct sequence for scanning by a predetermined selection of the

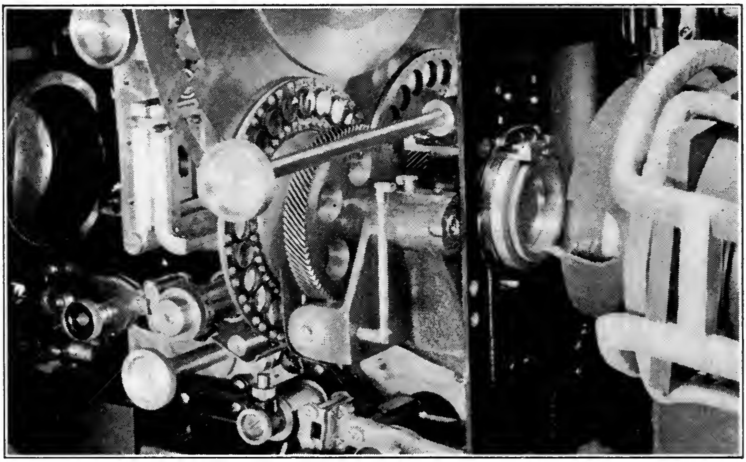

FIG. 4. Operating side of telecine projector.

projection lenses on the lens disks. Fig. 3 illustrates a method of selection in which a disk with spiraled slots rotates directly in front of the lens disks occulting all but the desired lens. The spiraled slot follows the lens in its downward travel and allows the projection of a single frame for a predetermined time, after which time the first lens is occulted and the next lens uncovered to project the following frame. The selector disk, as shown, is slotted to allow the projection of successive images of such time duration that they can be scanned alternately two and three times with a transition interval of less than $^1/_{600}$ second. By adjusting the phase relationship between the synchronous projector motor and the projector, the image transition

intervals are made to coincide with the scanning flyback intervals. The above allows scansion of single images with a minimum angular projection interval of the lens disks.

Fig. 4 pictures clearly the operating side of the telecine projector wherein the film is uniformly illuminated in the gate by a Mazda incandescent lamp, an image of the source being projected in the plane of the selector disk. A uniformly bright image is maintained during the projection interval by constriction of the slots in the selector disk according to the lens position in the light-spot. For the machine described, the amount of light so projected is in excess of 40 lumens. The image size can be modified by adjustments of the low-power auxiliary lens shown directly in front of the pick-up tube and the telecine camera racking table. Measurements of the image projected by the experimental machine indicate that the combined errors contributed by the gears, lens setting, *etc.*, are negligible and that within reading error, image unsteadiness does not exceed $^1/_8$ per cent.

SILENT GASOLINE ENGINE PROPELLED APPARATUS*

J. E. ROBBINS**

Summary.—*Problems are discussed connected with the design, construction, and operation of electrical generators and water pumps running under full load sufficiently silently to permit satisfactory sound recording. The units described were the result of demands for silent power equipment for making shots on boats, trains, bus interiors, inaccessible canyons, etc. As an example of what is sometimes required, one of the largest units was installed in the hold of a windjammer used throughout the Paramount Production "Souls at Sea" and although the microphone was at times directly above (approximately 30 feet) the spot occupied by the generator, no noises were picked up by the sound recording equipment.*

Four units are described, namely, one 144-kw. Hispano Suiza, one 57-kw. Lincoln Zephyr, and one 41-kw. Ford V-8 generator, and one high-pressure Ford V-8 water pump. In each case the entire mechanical unit is rubber-mounted on a sub-frame within a semi-airtight compartment constructed of an outer shell of 22-gauge auto-body steel, four inches of sound-absorbing material with an inner lining of asbestos cloth. The entire exhaust system is water-cooled, employing special mufflers also housed within the case. One radiator, mounted outside, cools the water for the engine as well as the exhaust. All are practically automatic in operation, with electrical governors, temperature regulators, etc. The machines have been in operation approximately fifteen months and have required very little service other than normal maintenance.

Prior to the advent of sound in motion pictures any reliable source of power, regardless of noise, was acceptable for operating generators, water pumps, and water churns on the lots as well as on location. Sound radically changed the entire condition. It was immediately necessary to move the equipment 800 to 1200 feet from the camera, depending upon conditions which were aggravated by changes in wind direction, difficult set-ups, enclosed canyons, *etc.* Effects of water in motion, ripples, and rain were generally shot sync (sound dubbed in later), due to the impracticability of obtaining working pressures from these distances.

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** Paramount Pictures, Inc., Hollywood, Calif.

Many futile attempts were made, in the years that followed, to silence the existing equipment. Failures were caused by the fact that openings had to be left on both sides of the machines to insure adequate cooling of the engines and generators. They would function properly with everything in their favor but would fail miserably when placed in boat holds, railroad cars, small barges, *etc.*

After seven years of such difficulties it was quite evident that the standards utilized in normal automotive practice would have to be

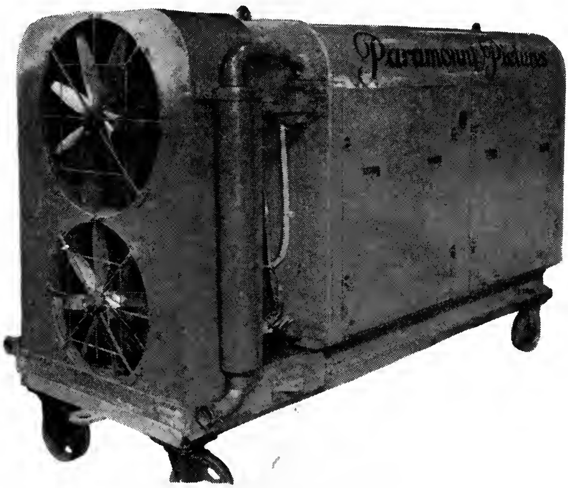

FIG. 1. Radiator end, Ford *V-8* generator. Note rubber mountings along bottom of frame. Fans operated by independent four-speed $^1/_4$-hp. motors. Hole between side doors serves as exhaust for main generator blower fan exhausting approximately 150 cubic-feet per minute.

abandoned and an entirely new design created. With this in mind our Engineering Department set out to build, on paper, the perfect power plant that would meet the following requirements:

(1) Be silent in operation.
(2) Be foolproof.
(3) Operate semi-automatically.
(4) Be light in weight.
(5) Be compact.
(6) Maintain constant voltage.

Very little calculation was necessary to prove that the only way to make it run silently would be to operate it in a vacuum, an im-

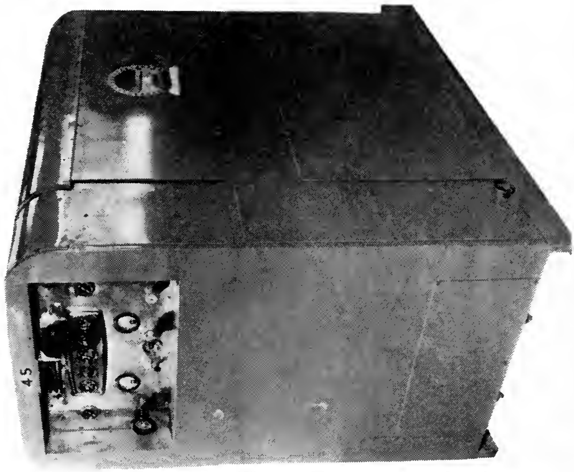

Fig. 3. Operating end, Lincoln Zephyr, showing instrument panel. Water-cooled mufflers mounted, center, in vertical position; air-cooled mufflers, also vertical, outside center within compartment behind instrument panel. Muffler outlet lower right corner; engine in upper compartment; generator, driven by silent chain, in lower compartment.

Fig. 2. Radiator end, Lincoln Zephyr generator, fans driven by *V*-belts from generator shaft. Right rear opening contains bus bars and circuit breaker.

practicable solution, of course. A sound-proof case housing the engine, coupling, mufflers, and generator seemed to present the next best medium. When entirely enclosed, the heat-dissipation problem had to be contended with. There could be no blast of air across the working parts, no huge body of water to circulate through the engine, as in the case of motorboat applications. All exhaust lines would have to be water-cooled. The magnitude of the problem will be readily understood when it is explained that approximately 1,200,000 Btu. per hour had to be carried off the motor alone.

The generators, in order to comply with requirements *4* and *5*, would have to be about one-half the normal output size, which is satisfactory as concerns portables but not for constant power-house service. Due to the fact that the average scene seldom exceeds fifteen minutes' duration, a 100 per cent overload is not unreasonable. However, these excessive loads do create heat and unless the heat is carried away immediately it will transfer from surface to internal with an attendant efficiency loss.

After carefully considering each problem, the final design was approved and the work started. For obvious reasons, various sizes were built, and will be referred to here as 350 (Fig. 1), 475 (Figs. 2 and 3), and 1200 (Fig. 4) ampere machines. These terms are strictly "motion picture" and are used in lieu of kilowatts when determining loads. Ford *V-8* engines were used in the *350;* Lincoln Zephyr in the *475* and Hispano Suiza in the *1200*, with standard commercial generators of 35-, 50-, and 85-kilowatt capacities.

The engines selected for the large machines were 300-hp. Hispano Suiza, wartime aviation type, picked because of their high output per pound of weight and their ability to withstand the punishment of long idling periods at 1800 rpm. as well as loads of one-half total capacity thrown on and off in rapid succession. Many changes were made in the motors before installation, in order partially to modernize them. New valves, different valve-springs, battery ignition system, modern fuel pumps, new carburetors, higher capacity oil pump, *etc.*, were used.

The engines and the generators, directly connected through especially designed pin and rubber flexible couplings, are mounted rigidly to a sub-frame which is in turn mounted on the main frame through commercial vibration dampeners (rubber in shear).

(Fig. 5) To the main frame, also mounted on the same type dampener, are bolted the two vertical ends of the sound-proof case. Four

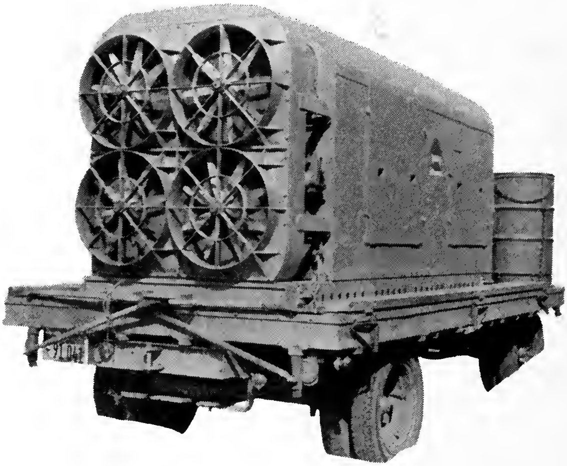

FIG. 4. Radiator end, Hispano Suiza.

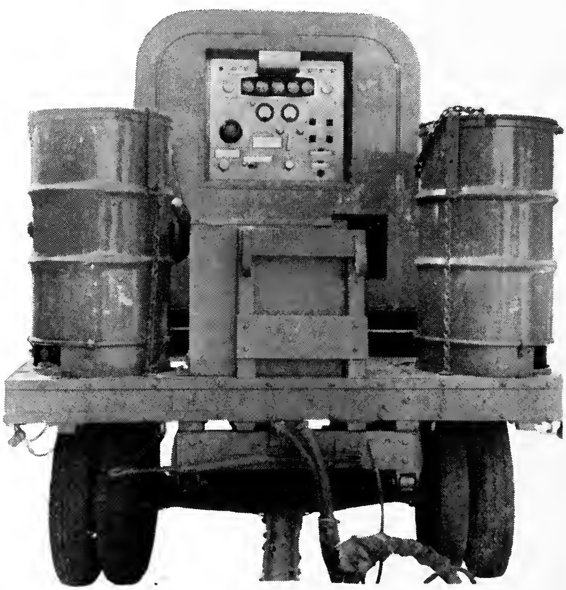

FIG. 5. Operating end, Hispano Suiza, showing gasoline tanks, instrument panel, bus bars. Entire unit lifts off trailer.

water and two exhaust lines come through one end, and on the opposite end are located the bus bars and the instrument panel, consisting of throttle, spark control, circuit-breaker, choke, ammeter, voltmeter, rheostat control, governor control, oil gauge, vacuum gauge and the switches for gas pump, oil pump, fans, and ignition.

The top cover, tunnel shaped, fits over these end pieces, resting on full-length strips of $^1/_2$-inch felt and bolts through the same dampeners to the main frame. The ends and top cover are fabricated of angle-iron framework. The outer cover is 22-gauge auto body steel. Next to this is placed a $1^1/_2$-inch thickness of corkoustic, a sheet composition of cork and felt, a 1-inch layer of hair felt, another $1^1/_2$-inch of corkoustic and an inner lining of asbestos cloth. All this is held in place by strips of spring steel.

The measured insulation of the 1200-ampere unit, using the generator as a source of sound is 22 db. The effective noise reduction is actually more than that due to the fact that valve noises are almost completely eliminated, but the high frequencies produced by the valve mechanism, while very objectionable during recording, contribute a relatively small amount of sound power as measured by a noise meter. The actual noise level of the machine at approximately three-quarter load, measured thirty feet away, was +60 measured with a General Radio noise-level meter using a 70-db. weighting characteristic.

The 350-ampere unit, again using the generator as the source of sound, is 24 db. The noise level measured at a distance of five feet is +65 measured with a General Radio noise-level meter, using a 70-db. weighting characteristic.

The exhaust system is comprised of five units (Fig. 6): the engine manifolds, elbows, water-cooled mufflers, outside leads, and the outer air-cooled mufflers. The manifolds, mufflers, elbows, and leads are all especially designed and are water-cooled. They are made of 16-gauge galvanized iron with 1 inch of water around all units. The inner mufflers are merely long tanks with perforated baffles spaced 2 inches apart. The outer air-cooled mufflers are used only when operating in very close quarters. The efficiency of this set-up can best be explained by the fact that normal full-load temperatures, at the port, 1300°F, are reduced to approximately 120°F at the tail pipes. This reduction, with the attendant contraction of gas pressures, minimizes the possibility of drumming and whistling noises.

The radiator sizes, number and capacities of fans and fan motors,

inlet and outlet flows, and other cooling factors (Figs. 1, 4, and 7) were determined by using the standard formulas and ratios of transference of metal to water to metal to air plus 15 per cent. The added 15 per cent was figured to compensate for the normal loss of radiation by air across the engine and to allow for a longer period of high load time with the fans on low speed. To date, no absolutely silent air delivery fans are available, to our knowledge. The fans used are 24 inches in diameter with eight blades, and are independently driven by $^1/_2$-hp. four-speed, 250-, 500-, 800-, and 1100-rpm., d-c., motors controlled by switches on the instrument panel. At top speed each fan

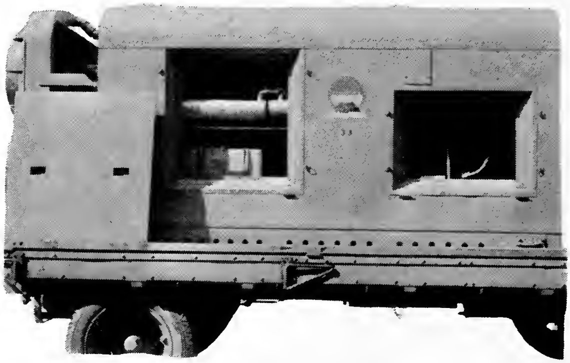

FIG. 6. Hispano Suiza generator plant with engine and generator door openings. Note water-cooled exhaust manifold (through left opening) with flexible water-cooled connection between manifold and elbow running to water-cooled mufflers above.

actually delivers 4000 cubic-feet per minute. To reduce static pressures, the air is pulled from behind through the radiator and then through the blades. The fan motors are kept cool in this manner and the possibility of chopping noises is also diminished. With this set up it is possible to run the unit under full load for 18 minutes allowing the water temperature to change from 140° to 190°F on the low silent fan speed. At the end of the shot, the switches are turned to high speed and with no load the water temperature can be dropped back to 140° in 4 minutes.

Under full load, the temperature inside the motor housing seldom exceeds 110°F. To maintain this temperature, air is drawn through a sound-trap in the floor of the set, up across the generator armature

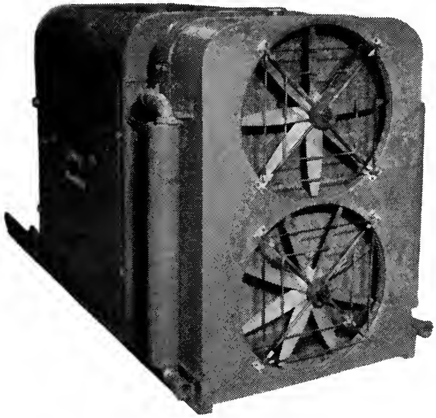

FIG. 7. Radiator end Ford *V-8* water pump; water-cooled mufflers inside box, air-cooled mufflers along both sides of radiator. Fans driven by *V*-belts off extended motor shaft.

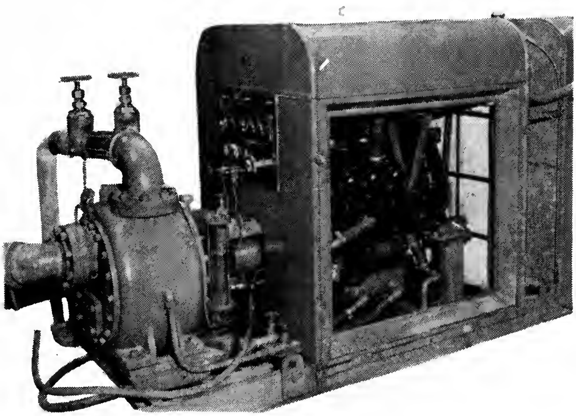

FIG. 8. Pump end, Ford *V-8* water pump. Door removed to show rubber engine mountings, crankcase enlargement for greater oil capacity, and space for circulating coils for water from outside pump. Brackets on cylinder heads support water-cooled mufflers. Asbestos inner lining and spring steel strips for holding insulation in place. Automatic engine vacuum-operated pump-primer shown just behind coupling.

and into the carburetor. On the first machines an additional scavenger system was needed to offset the difference in engine air consumption at idling speeds. The latest unit, the 475-ampere Lincoln Zephyr, is built with the motor in a separate compartment over the generator (Figs. 2 and 3). The air, in this instance, is drawn up through the lower compartment into the carburetor. In this manner, no engine heat ever reaches the generator and the entire unit runs cooler without the aid of extra blowers.

In many recent boat hold installations, this particular design has proved especially advantageous. In *Souls at Sea*, a recent Paramount production, two sets were placed on the second deck, approximately 12 feet below the main deck. Flumes connected to the front of the radiator carried all heat and gases to the rear portholes and outside. No masks were required by the operators and no sound was detected by the microphones.

The large machines are 12 feet long, 60 inches high, 56 inches wide, and weigh 10,000 pounds. They are all electrically governed. The governors used can not be obtained commercially. They are especially designed such that it is impossible to exceed a predetermined voltage setting. Also, they are so constructed that their throttle opening action is instantaneous, which obviously prevents the possibility of decreased voltage which would materially affect the value of the light. A 10-volt variation in either direction would be immediately detected by the camera. This regulation may not appear difficult. However, 50 rpm. on the motor will account for a differential of approximately 8 volts. The reaction of the motor when instantly relieved of two-thirds of its load is similar to what would happen if the drive shaft of an automobile should snap while being driven up a slight grade with a full throttle at 60 miles per hour. The opposite action takes place when loads are put back in like proportions.

As previously explained, six generators of the same design have been constructed in various sizes. To date, the only unit other then the previously described generators, is a high-pressure water-pump (Fig. 8). This unit employs a Ford *V-8* engine and a two-stage 4 × 4-inch pump. The motor is entirely enclosed, as in the case of the generators, but the pump is outside.

For creating eddies, waves, and water in motion, we have designed a portable propeller machine that will be gas-engine driven as described above. It will be very silent. No radiator will be used, the water being circulated from a pool so that no fans will be required.

No absolutely silent air mover is available at present. All types were investigated at the time of construction and many peculiar designs to accommodate squirrel-cage and other types considered before going to the accepted multi-blade fan.

The 1200-ampere machines outside have been used successfully 200 feet from the cameras; the Lincoln Zephyr, 150 feet; and the Fords, 100 feet. Twelve feet was mentioned previously; however, that was in connection with a boat where the deck afforded additional insulation. Such distances may seem excessive, but for the reader's satisfaction, he may set the hand throttle of his automobile at approximately 60 miles per hour speed, in neutral gear, start walking out in front of the car, and measure the distance when he can no longer hear the engine.

A TECHNIC FOR TESTING PHOTOGRAPHIC LENSES *

W. C. MILLER**

Summary.—*Different makes of lenses have different properties and characteristics that may render a lens good for one purpose and totally undesirable for another. Lenses of a given make and series often vary in quality among themselves. To obtain the best lens for a specific purpose it is necessary to subject the various makes to tests that will reveal their characteristics. Once the type of lens for a specific purpose has been chosen, it is of great importance to be able to select the best of that type from a group submitted by the manufacturer.*

Equipment and technic used in tests that make such discrimination possible are described. A few general hints and precautions are given that will aid in determining the characteristics most desirable for various purposes.

Due to the vast number of lenses available at the present time, the prospective buyer is faced not so much with the question of where to get lenses as which lenses to choose from the multitude presented to him. With so many, each with its various features, it becomes a serious task to select a certain make and be sure that it, more than any other, possesses the qualities required. It is impossible to detect any but the grossest errors by merely holding the lens in the hand and looking through it. And since lens makers, in common with most other manufacturers, describe their products to the best advantage, one is at a loss to know how to decide which lenses possess the characteristics most desired.

Lens manufacturers have always been loath to publish critical data concerning their products. Until they consent to do so the purchaser must find means for himself of determining which of the many lenses available possess the qualities that best fill his needs. It is not an easy task, especially since the science of optics is avoided by most persons as being in the realm of the supernatural and comprehensible to only a few chosen master-minds. This is totally unfounded, as the fundamentals required for a working knowledge of lenses and lens testing

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received Aug. 12, 1938.

** Paramount Pictures, Inc., Hollywood, Calif.

are no more difficult to acquire than those required for work in sound, electricity, or radio. They have merely been shrouded in a cloak of mystery that has frightened away many an interested student. It is time that anyone having anything to do with lenses in any capacity learns how to tell the good from the bad. This paper gives a few elementary tests that anyone can comprehend and carry out, and a few simple principles that will be of service to anyone faced with the necessity of selecting new lenses.

It is possible to go to great extremes to detect errors in lenses. It is therefore necessary first to determine just what extremes are justified. This depends primarily upon how the lens is to be used and what is to be expected of it. Once that has been determined it is possible to set up equipment and a technic that will reveal the characteristics of interest.

The tests and specifications outlined here are intended primarily for use with standard 35-mm. camera lenses. The principles are, however, applicable to lenses of other types with slight modifications. The tests will be found to be sufficiently searching for ordinary production lenses. Added refinements and still other tests can be made when occasion demands.

Since no lens designer is as yet able to design a lens free from all aberrations, every lens is necessarily a compromise between numerous errors. Various designers feel differently about which aberrations should be sacrificed for others, so that almost every make of lens performs in its own way. It therefore becomes our task, once we have decided what characteristics are most desirable, to choose the lenses whose corrections lend themselves most advantageously to our purposes.

More than that, once the type or make has been selected, it is necessary to test the individual lenses before they are purchased, to eliminate any that fall below certain standards. Lenses of a given make vary among themselves as do other commercially manufactured products. True, certain tolerances are placed upon them by the makers, but it is wise to check each lens to make sure that the manufacturers' tolerances are acceptable.

It would be unwise to stipulate here certain definite qualities which should be required of any lens; these can be determined best by the individual user from experience, personal preference, and the demands of the job at hand. A few of the more general characteristics common to lenses will be mentioned and methods given for detecting them.

Some of the most insidious evils that need not, and should not, be tolerated will be so specified. But the degree to which the other corrections must be carried is, of necessity, left to the user's own good judgment.

The fundamental principle to be kept in mind when using modern lenses and panchromatic film stock is that all colors to which the film is sensitive must come, within small limits, to a common focus. Modern lenses can be held within such small tolerances in this respect that there should be no detectable discrepancy between the foci of the red, the green, and the blue light when the lens is tested photographically on a suitable target.

A satisfactory target for this test can be made by ruling on a white card of adequate size a series of parallel, horizontal lines separated by about an inch and numbered each way from the center-line. This target is set up a short distance in front of the camera at an inclination of about 45 degrees and evenly illuminated. With the lens focused on the central line, a series of exposures is made of this target, using a standard set of tricolor filters. No change should be made in the focal setting of the lens between exposures. Any change of the *relative* sharpness of the lines of the target seen on the resulting negatives is an indication of the extent by which the various colors fail to come to a common focus. There should be no detectable difference in any of the three images taken with a good lens. If some color fails in actual practice to come to a common focus when the lens is used with panchromatic stock, the resulting image will not be sharp and clear.

For lenses that are to be used only with stock sensitive to the blue or blue-green this restriction is not so great, for in that case should the red light fail to come to the same focus as the blue and green, the photographic image would not suffer as the film is insensitive to the red. It is therefore unnecessary to pay the extra price for panchromatic lenses unless they are to be used with panchromatic stock.

When a lens is focused wide open the image may be as sharp and clear as desired; but when the iris is stopped down preparatory to making the exposure, the images formed by some lenses will be found to go out of focus without any movement of the lens itself. This is due to zonal spherical aberration in the lens, and is often called "diaphragm focus." To recapture the sharpest possible image it is necessary to refocus the lens, using the aperture at which the exposure is to be made.

In selecting new lenses a series of exposures should be made of the test-chart used in the color test, first with the lens wide open at its best visual focus, and then at selected smaller apertures with no change in the focal setting of the lens. Upon examination of the negatives, the change in the apparent focus of any of the exposures should be negligibly small. Most of the modern fast lenses show this "diaphragm focus" to a greater or lesser degree. The user must determine just how much he can tolerate.

Any lens already in use that displays diaphragm focus should always be focused at the aperture at which the exposure is to be made. This is often difficult to do when a small stop is required, but it is the only way to be sure that diaphragm focus will not influence the sharpness of the picture.

Some types of lenses show a tendency toward internal reflections that give rise to "flares" or "ghosts." Such a tendency can be detected easily by placing a ground glass in the focal plane of the lens and moving a bright light some distance in front of the lens all about the field of view while watching the ground glass.

Any tendency of a lens to produce flares in actual use will be greatly enhanced and the relative merits of various makes can be judged. Generally the fewer air-glass surfaces there are, the less is the tendency to cause flares. Consequently slow lenses of the three-element type should be favored when a scene requiring great contrasts is to be photographed.

All lenses possess a characteristic that finds such frequent use that, although it is in nowise a test, it deserves mention here. When a lens is focused upon a point A a given distance away, other points lying short distances in front of and behind A will also be in fair focus. It is found that the focus carries with reasonable sharpness a greater distance behind A than in front of it. If two other points, B and C, are chosen, one before and one behind A, which are equally sharp, they will occupy definitely specified positions with respect to the lens and the point A. It is therefore possible to determine just where to focus between two objects to make them both appear equally sharp in the picture, provided one knows the distances of the two objects from the lens. Substituting the distances B and C in the formula

$$A = \frac{2BC}{B + C}$$

the result is the distance from the lens to the intermediate point A.

As an example assume that one person is standing 10 feet from the camera and another 30 feet. A is then 15 feet, and if we focus upon a point at that distance, both objects will register with equal sharpness. This method gives results that are amply accurate for ordinary use. Whether or not the two objects will be perfectly sharp depends, of course, upon such factors as the focal length of the lens and the aperture used.

The optical definition of a lens, or its ability to render clearly small detail within its usable field, is a quality that can vary greatly depending upon the purpose for which the lens is intended. For portraiture sharp definition is rarely desired, particularly around the field. For ordinary work, where that illusive property known as "quality" is desired, more definition is needed, but more uniformly distributed over the field. For miniatures, process work, or for pictures that are to be greatly enlarged, every bit of definition that can be had is usually required over the entire field. Likewise for optical printing and copying. Therefore, depending in what field of work the lens is destined to be used, various amounts and distributions of definition must be selected.

To test a lens for definition all that is required is a chart upon which are placed cards bearing lines of letters or numbers of gradually decreasing size, much like the Snellen charts used in testing the eyes. With these cards distributed advantageously over the chart, exposures can be made with the various lenses at their positions of sharpest central focus. Care must be taken to see that the test-chart covers the entire usable field of the lens in order that the character of the image in all parts of the field can be studied. Also the lens must shoot squarely at the center of the target, for if it is cocked one way or another misleading results will be obtained.

Examination of the resulting negatives under sufficient magnification will reveal that different types of lenses have different degrees of definition in different parts of the field. But it will be found that for equal definition at the center some lenses will have much better definition at the edges than others. These are said to have better "covering power."

To determine how much definition is required and how it should be distributed over the field requires experience and skill. For the uninitiated the best way to determine this quickly is to test lenses that are giving satisfactory results in production and to select any new lenses that have about the same correction. Experiments with new

types of lenses may reveal that even better results can be attained with some of them.

A defect often found in lenses is known as "chemical focus." Expressed simply, this means that the focal setting determined visually does not agree with the one found photographically. In reality it is due to peculiarities of the color correction, but it often shows up as if it were a separate characteristic. It can be checked by focusing a lens visually for best central definition and then making a series of exposures at the same setting and at others departing by small amounts on either side of the visual one. It will be found that steps of 0.001 inch will be satisfactory. If it is found that the negative having the sharpest central definition has a setting other than the visual one the lens has the chemical focus of the amount of the discrepancy. In bad cases with short-focus lenses this may amount to many thousandths of an inch. A lens showing more than two or three thousandths should be rejected.

A lens will be encountered occasionally that vignettes due to improper construction. Some lenses do so when wide open, the edges of the lens mounts cutting in at the corners of the picture. These can generally be improved by stopping down the iris. Sometimes vignetting increases when a lens is stopped down, and is due to the improper location of the iris with respect to oblique rays of light passing through the lens.

These two conditions can be checked by making exposures with the iris wide open and again stopped down to about $f/9.0$. If the corners of either negative are cut in, the lens should be rejected. Obviously, care must be taken to insure that no lens shade or matt box in front of the lens is the offending member.

A peculiar effect is obtained with some lenses in motion picture work when a scene is "panned." An object entering at one side of the field grows or shrinks in size as it moves across the picture, again returning to its former size at the other edge. The fault shows itself also when the lens is used to photograph architectural subjects: lines near the edge of the field are bent either in or out. It is very disconcerting if this tendency is pronounced. To obtain good pictures, lenses should be used that do not display such a characteristic. A quick way to determine whether they will or not is to project, by means of the lens under test, an accurate aperture plate whose opening is equal to the film aperture for which the lens was designed. If the projected image of the aperture as seen upon a screen is defined by straight boun-

daries, the lens is free from this trouble. However, if the edges of the image are curved, bending either in or out at the middle, this disturbing effect will be obtained with the lens in use.

To determine how much distortion is present, measure the height of the projected aperture image at one side and again at the center. The difference of the measurements divided by the smaller should not exceed 0.005. Lenses in which this quantity is as small as 0.001 are obtainable.

The effect obtained by panning with lenses having distortion should never be confused with the effect of panning about an axis not coincident with the optical center of the lens. The latter condition gives rise to changes of perspective due to swinging the lens in an arc. This also causes certain undesirable effects on the screen. To obtain perfect optical results when panning, the lens must be free from distortion and must be swung about a vertical axis running through the optical center of the lens. This insures that there will be no disturbing changes in the sizes of objects passing across the field and changes in perspective and point of view.

Another test that should be made can best be done in a machinist's lathe. The lens should be mounted and accurately centered on the threads and shoulder of the lens mount. If a small light is then placed in such a position that its reflection can be seen in the various lens surfaces, it will often be found that these reflected images will move when the lens is rotated slowly in the lathe. When such is the case, it indicates that the individual glass elements are not truly centered in the cells. Often the effect will be visible in a number of the elements at once.

Although a small eccentricity of the elements is rarely detectable in the image, it does have an effect. If several of the elements are eccentric the total effect will be very noticeable and undesirable. It takes experience to determine how much is tolerable.

The user or prospective purchaser of the lens should never attempt to center the elements in their cells; it is a job for the manufacturer. In fact, lenses should never be taken apart to the extent of removing the glass elements from their cells, for they can rarely be put back into exactly their original positions. An excellent lens can be spoiled by not centering all the elements correctly on the optical axis.

After years of work with lenses one becomes aware of a quality of optical images that can be described only as "contrast" or "brilliance." It is completely separate from the contrast obtained due to

to the processing of the film or print, and is inherent in the image of the lens whether photographed or viewed visually. It makes a great difference in the results attainable with a lens whether or not the lens possesses this desirable quality. In general, it is due to the type of lens: the fewer the number of air-glass surfaces the more brilliant the image. But it is due also to other things such as the polish of the lens surfaces and their cleanliness, both of which affect the amount of diffused and scattered light in the image plane and thereby the brilliance of the image. There is often detectable among lenses of a given make and focal length a difference in the contrast of the image. In selecting lenses this should be watched for and any lens, however perfect otherwise, that gives a flat, dull picture, should be discarded.

Frequent tests of lenses in constant use will be found very advantageous. Accidental damage of a minor nature, or looseness of the lenses in the mounts due to vibration or shock, can be detected and remedied before they become so serious as to impair production. Deterioration in optical performance can be detected and traced to its source, and can often be remedied if caught in time. The most common occurrence of this sort is the "feathering" of the balsam used to cement some of the glass elements together. The lenses can be cleaned thoroughly when they are tested by someone skilled in this type of work. More lenses are damaged by careless or ignorant cleaning than by any other cause.

Absorbent cotton is cheap, soft, and in every way one of the best cleaning materials available. Breathing gently on the surface will moisten it and greatly facilitate the removal of dust and spots. Cleaning solutions and soaps should be avoided whenever possible. Anything that will not yield to the moisture of the breath can be removed by barely moistening the cotton with carbon tetrachloride. Nothing more severe than this should ever be used. Always clean lenses with a circular motion, blowing strongly against the surface with the last few strokes to remove any lint.

Careful application of the principles outlined in this paper for the selection of lenses will be found to improve greatly the quality of the resulting pictures. The results attained on the screen can be no better than the lens that made them. It is therefore useless to lavish money on sets and costumes that will never show clearly on the screen due to poor lenses on the cameras. Greater improvement will be obtained in proportion to the required expenditure by using the best lenses available and keeping them in good condition by constant care.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

***Summary.**—This report contains the reports of four of the Sub-Committees of the Projection Practice Committee, viz., on the Motion Picture Theater Survey, on Screen Illumination, on Projection Room Plans, and on the Proposed Revision of the NFPA Regulations for Nitrocellulose Motion Picture Film. A preliminary report is rendered by the Sub-Committees on Theater Survey and Screen Brightness. The Projection Room Plans and Revision of the Fire Regulations are presented in full.*

During the past year, the Committee has been engaged in a number of important projects, the principal ones being the following:

(*1*) Motion picture theater survey.

(*2*) Study of screen brightness and methods of measuring it.

(*3*) Revision of the Projection Room Plans.

(*4*) Revision of NFPA Regulations for Handling Nitrocellulose Motion Picture Film.

(*5*) Study of the tolerances and clearances permissible in motion picture projection equipment and means of measuring and checking these values.

As these projects involve a great deal of work and require considerable time for complete study, it will not be possible to report on them all at this time. The present report deals only briefly with item *1*, since, following the publication of the comprehensive theater survey last spring, more time is required for analysis of the data and formulation of recommendations. With regard to item *2*, the Committee has long been searching for suitable means of measuring screen brightness in theaters, and the present report of the Sub-Committee indicates considerable progress in solving the problem.

Items *3* and *4* are dealt with in great detail in the present report. With regard to projection room plans, it is the hope of the Committee that all those who contemplate building new projection rooms or revamping existing projection rooms, will give serious thought to the recommendations contained in these Plans. The Fire Regulations are subject to revision pending action by the Committee on Hazardous Chemicals and Explosives of the NFPA, to whom the proposed revision has been submitted. This matter is more fully described in the preamble of the report, on p. 498.

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* Presented at the Fall, 1938, Meeting at Detroit, Mich.; received September 20, 1938.

Work on project *5* has just about begun, so that no more can be done at the present time than to state that this subject is receiving the earnest attention of one of the Sub-Committees.

The Chairman wishes to commend the various members of the Committee who have worked so hard and spent so much time on these projects. It is felt that the reports of the Committee presented at both this and the last Convention represent contributions of major importance to the motion picture industry.

PROJECTION PRACTICE COMMITTEE
H. RUBIN, *Chairman*

THEATER SURVEY

Report of the Sub-Committee on Theater Structures, comprising an analysis of a survey of theaters of the industry as regards their physical dimensions and structural proportions, was presented at the last Convention as was published in the June, 1938, issue of the JOURNAL. This report has aroused considerable interest among motion picture theater architects both here and abroad. Although the work has not yet progressed to the point where the data of the survey can be used for determining ideal structural conditions for projecting and viewing motion pictures, the work is proceeding and it is hoped that the Sub-Committee may be able to report on the subject at the next Convention. The subject is a complex one and requires very careful analysis.

In connection with the rising interest throughout the industry in good projection and good viewing in motion picture theaters, the Projection Practice Committee has thought it advisable to state specifically its policy with regard to the view of the screen provided for each patron of the theater:

The Committee regards clear and unobstructed viewing of the screen as an essential and major factor in audience satisfaction. It disapproves any form of auditorium design or seating arrangement that will prevent any patron from seeing all parts of the screen at all times, regardless of the positions of other patrons.

There are several degrees of obstruction of view of the screen. Arranged in order of diminishing desirability, these are:

(*1*) Clear vision regardless of positions of patrons one or more rows ahead.
(*2*) Clear vision regardless of positions of patrons two or more rows ahead.
(*3*) Partially obstructed vision under almost any conditions.

To reduce obstruction of view, there are several methods available, including the following:

(*a*) Staggering the seats of successive rows (which may reduce the number of seats or cause "ragged" aisles).

(*b*) Raising the level of each row of seats relative to the row before it (which may lead to an impracticable amount of rise in some theaters from front to back).

(*c*) Adopting a suitable combination of fall and rise of successive rows of seats from front to back (which method requires further study in practice on a wider scale under various conditions).

One or more of these methods should be seriously considered by theater architects. In no case does the Projection Practice Committee approve any seating arrangement falling appreciably below Grade *1* above; that is, the Committee disapproves any noticeable obstruction of the screen view of one patron by any other normally seated patrons no matter where located.

SUB-COMMITTEE ON THEATER SURVEY
B. SCHLANGER, *Chairman*

SCREEN ILLUMINATION

The product that the motion picture theater offers to the public is the picture on the screen. The two essential factors in the production of a good screen picture are the film, over which the exhibitor has no control, and the projection light. It is only through the provision and maintenance of an adequate light-source that the management can exercise control over its product.

During the past few years theater owners and managers have become light-conscious. This has brought about the necessity for a small, compact, portable, and inexpensive light-meter that can be as easily read as the ordinary voltmeter or ammeter. With these considerations in mind the Projection Practice Committee set out to determine the best type of meter obtainable.

There are three places at which the light might be measured:

(*1*) Directly in front of the projector.
(*2*) Incident upon the picture screen.
(*3*) Reflected from the picture screen.

The provision of a single instrument capable of making all three kinds of measurements was considered, and was rejected for the reason that such a meter, like all previous instruments, would be too cumbersome, complicated, and expensive for general use. On the other hand, a meter capable of measuring the light incident upon the picture screen fulfills the needs of 95 per cent of the light-measuring

requirements. At the same time such a meter is both simple and low in price (Fig. 1).

A meter of this type has been developed, with which is provided a visual correction filter which the Committee feels is essential to the accurate evaluation of light-sources in terms of human eye response. Tests with this meter calibrated in tungsten light at 3000°K showed that the errors, when measuring low- and high-intensity arc sources were less than 3 per cent.*

The meter reads from 0 to 30 foot-candles. It was felt that this range was ample for present commercial levels of screen illumination inasmuch as many theaters do not average more than 4 to 8 foot-candles although the SMPE recommended average is about 10 to 20 foot-candles with the shutter running.**

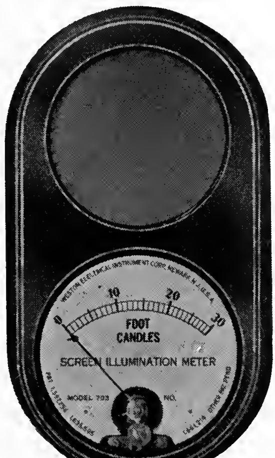

FIG. 1. Screen illumination meter.

In using the meter for measuring screen illumination, it is recommended that nine readings be taken as follows: At the center of the screen, at the four corners, and at the centers of top, bottom, and both sides. When making a measurement the meter is held flat against the screen, the cell opening facing the projector, with the projector shutter running and no film in the gate.

These readings not only measure the incident light but also indicate the uniformity of distribution of the light, which is ordinarily expressed as the ratio between the readings at a side and at the center. A ratio of 80 per cent is considered very good and is obtainable by manipulating the optical system of the projector lamp in a manner familiar to all projectionists.

SUB-COMMITTEE ON SCREEN ILLUMINATION

E. R. GEIB, *Chairman*

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* Of the meters available for such measurements, the one tested by the Sub-Committee was the new Weston model *703*.

** Actually 7 to 14 foot-lamberts.

PROJECTION ROOM PLANS

The projection room plans that follow represent the third revisio of the plans originally published by the Committee in August, 1932 The second revision appeared in October, 1935.[1] Such revisions ar necessary from time to time in order to keep pace with the change and developments in the art and practice of projecting sound motio pictures. The Committee urgently recommends the adoption o these recommendations by all architects and builders in designin and remodeling projection rooms so that greater uniformity of con struction and greater efficiency in projection will exist in the future

In following these recommendations, proper authorities should in all cases, be consulted for possible deviation therefrom. An fire-protection requirements specified herein are in accordance wit the Regulations of the National Board of Fire Underwriters and th National Electric Code, which should be consulted for details.

Projection facilities shall consist of (*1*) the projection room proper (*2*) a film rewind and storage room, (*3*) a power equipment room and (*4*) a lavatory (Fig. 1).

PROJECTION ROOM PROPER

(*1.1*) *Construction.*—The projection room shall be fire-proof, an shall be supported upon or hung from fire-proof structural steel o masonry. It shall have a minimum height of 8 feet and a minimu depth of 12 feet. The length of the room shall be governed by th quantity and the kind of equipment to be installed, but shall in n case be less than 16 feet. Consideration should be given to probabl future needs.

The Committee recommends that the projection room prope be so located with respect to the screen that the vertical projectio angle shall not exceed 18 degrees. Optical axes of the projector shall be 5 feet apart. When two projectors are used, the optica axes shall be equidistant from the center-line of the auditorium when three projectors are used, the optical axis of the center projecto shall be on the center-line of the auditorium.

(*1.2*) *Floor.*—The floor of the projection room shall be sufficientl strong and solid for the load it is to bear, and shall be constructed i accordance with local building regulations. A generous factor o safety should be allowed. A type of construction recommended b the Committee consists of (*1*) a reinforced concrete floor-slab not les than 4 inches thick; (*2*) a tamped cinder fill above the floor-slab, not les

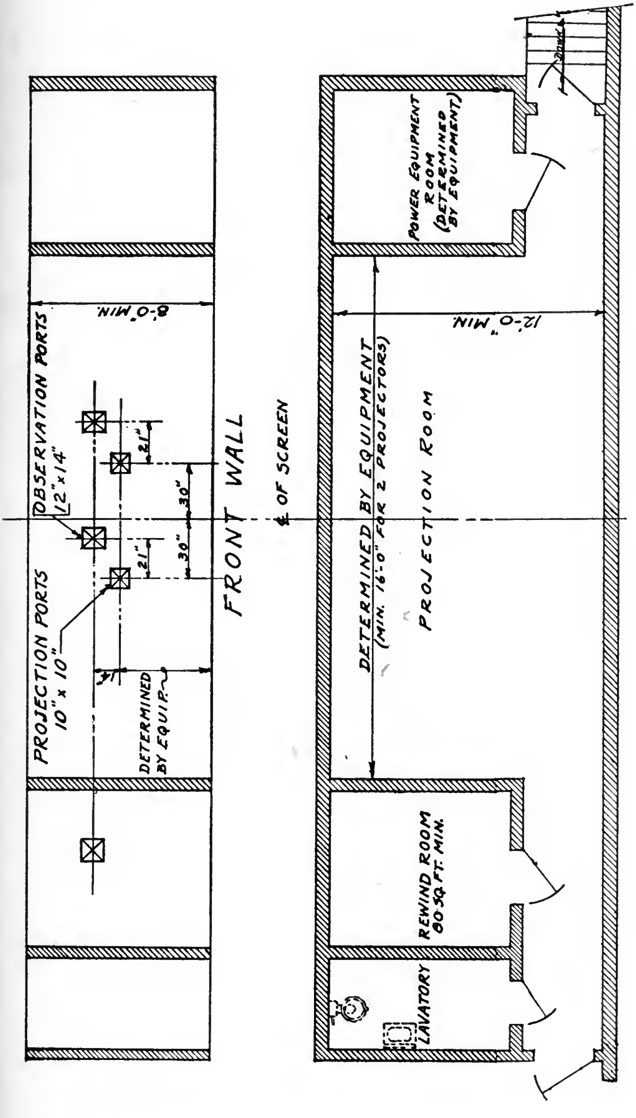


FIG. 1. Functional diagram of projection and associated rooms, showing arrangement for two projectors.

than 2 inches thick; and (*3*) a troweled cement finish above the cinder fill not less than 2 inches thick. Items (*2*) and (*3*) have been provided in order to accommodate concealed electrical conduits, which should be installed prior to placing the fill and finish. (See Sec. *6.1.*)

(*1.3*) *Walls.*—The projection room walls shall be built of brick, tile, or plaster blocks plastered on the inside with $^3/_4$-inch cement plaster, or all concrete. The core of the wall shall be not less than 4 inches thick. When plaster block is used, it shall be supported upon steel framework. All electrical conduits shall be placed into masonry chases in the wall construction so that no pipes shall project beyond the main finish line. (See Sec. *6.1.*) In all cases, the inside surface of the front wall shall be smooth and without structural projections. (See Sec. *1.11.*)

(*1.4*) *Doors.*—A door shall be provided at each end of the projection room, at least 2 feet 6 inches wide by 6 feet 8 inches high. Doors shall be of the approved 1-hour fire-test type and shall be arranged so as to close automatically, swinging outwardly, and shall be kept closed at all times when not used for egress or ingress. It shall be possible at all times to open either door from the inside merely by pushing it. Door jams shall be made of steel.

(*1.5*) *Windows.*—Where a projection room is built against the exterior wall of a structure, one or more windows may be provided in the wall. Window construction shall be entirely of steel, and the glass shall be of the shatter-proof type. Metal adjustable louvres or other similar means may be used to exclude light.

(*1.6*) *Ports.*—(*General.*) Two ports shall be provided for each projector or single-lens stereopticon, one through which the picture is projected, known as the "projection port" (see Sec. *1.7*), and the other for observation of the screen by the projectionist, known as the "observation port" (see Sec. *1.8*).

The observation port shall be located above and to the right of the projection port. The distance between the horizontal center-lines of the projection port and observation port shall be 14 inches; the distance between the vertical center-line shall be 21 inches.

Where separate spotlight or floodlight machines are installed in the same projection room with motion picture projectors, not more than one port opening (see Sec. *1.9*) for each machine shall be provided for both the projectionist's view and for the projection of the light, but two or more spotlights or floodlights may be operated through the same port.

(*1.7*) *Projection Ports.*—The finished ports shall be 10 × 10 inches, measured on the inside wall (Fig. 1).

The required height of the center-line of the projection port from the floor varies with the make and design of the projection and sound equipment and also with the projection angle. Manufacturers of equipment being considered for the projection room should be consulted for these dimensions. In no case shall any part of the projector be less than 4 inches from the front wall of the projection room. Table I lists two constants for various angles of projection which when substituted in the formula, will permit calculating the height of the center-line of the port from the floor, when certain dimensions of the projector are known.

(*1.8*) *Observation Ports.*—The finished observation port shall be not greater than 12 inches wide × 14 inches high, measured on the inside wall of the projection room.

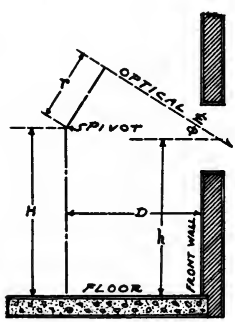
(*1.9*) *Other Ports.*—All other ports, such as for effect projectors

TABLE I

Method of Locating Projector Port

$$h = H + rA - DB$$

Projection Angle (Degrees)	A	B
0	1.00	0.00
2	1.00	0.04
4	1.00	0.07
6	1.01	0.11
8	1.01	0.14
10	1.02	0.18
12	1.02	0.21
14	1.03	0.25
16	1.04	0.29
18	1.05	0.33
20	1.06	0.36
22	1.08	0.40
24	1.09	0.45
26	1.11	0.49
28	1.13	0.53
30	1.16	0.58



H is the height of the center of the projector pivot from the floor; r is the radial distance of the optical center-line above the center of the pivot; D is the distance of the center of the pivot from the front wall of the projection room; ϕ is the angle of projection; and h is the required height of the center of the port from the floor of the projection room. Select the values of A and B corresponding to the angle of projection, and substitute in the formula.

or spotlamps, shall be as small as practicable, and in no case shall exceed $7^1/_2$ square-feet in area per machine. The location of these ports will, of course, be determined by the dimensions of the equipment and the size and shape of the auditorium and stage, which determine the angles through which the light-beams must be projected. The dimensions should be obtained from the manufacturers of the equipment.

(*1.10*) *Ceiling.*—The ceiling shall be constructed of 4-inch concrete slabs or precast concrete, or of 3-inch plaster blocks supported by a steel structure and plastered on the inside with $^3/_4$-inch cement plaster. All wiring conduit in the ceiling shall be concealed (see Sec. *1.11*).

(*1.11*) *Acoustic Treatment.*—It is recommended that an approved fire-proof acoustic material be used on the walls above a height of 4 feet from the floor and on the ceiling to reduce the transmission of noise into the auditorium.

REWIND ROOM

(*2.1*) *Construction.*—The rewind room shall be of fire-proof construction. It shall have a minimum area of 80 square-feet (Fig. 1).

(*2.2*) *Floor.*—See Sec. *1.2*.

(*2.3*) *Walls.*—See Sec. *1.3*.

(*2.4*) *Doors.*—The door shall be of the approved 1-hour fire-test type, shall be arranged so as to close automatically, swinging outwardly, and shall be kept closed at all times when not used for egress or ingress. Door jams shall be made of steel.

(*2.6*) *Ports.*—An observation port shall be provided through which the motion picture screen may be seen from within the rewind room. The port shall be at the same height from the floor as the observation ports in the projection room proper, as described in Sec. *1.6*.

(*2.8*) *Observation Port.*—See Sec. *1.8*.

(*2.9*) *Other Ports.*—An observation window shall be provided between the projection room and rewind room, consisting of a fixed, fire-proof frame and polished plate wire glass. The window shall be not greater than 14 inches square.

(*2.10*) *Ceiling.*—See Sec. *1.10*.

(*2.11*) *Acoustic Treatment.*—See Sec. *1.11*.

POWER EQUIPMENT ROOM

(*3.1*) *Construction.*—The room shall be fire-proof and shall be similar in construction to the rewind room (with the exception of the openings (see Fig. 1)). The size shall be governed by the quantity and kind of equipment to be installed. Consideration should be given to probable future needs.

LAVATORY

(*4.1*) *Construction.*—The lavatory shall be provided with running water and modern sanitary facilities, with tiled floor and built-in flush-type medicine closet.

EXITS

(*5.1*) *General.*—Two exits shall be provided, one at each end of the projection room suite (Fig. 1), permitting direct and unobstructed egress, and shall conform to the regulations of local authorities having jurisdiction. Any stairs communicating with these exits should have risers not in excess of 8 inches and minimum tread of not less than $9^1/_2$ inches. The distance between walls should be not less than 36 inches. Winding or helical treads should be avoided. A platform equal in length to the width of the door shall be provided between the door and the first riser. Neither ladders nor scuttles or trap-doors should be used as means of entrance or exit.

CONDUITS AND CIRCUITS

(*6.1*) *Locations and Sizes.*—Locations and sizes of conduits for projection, control, and sound equipment are determined by the type and design of the equipment. Manufacturers of the equipment should be consulted with regard to the proper layout and sizes of the conduit systems before floors, walls, and ceilings are finished (see Secs. *1.2* and *1.3*). Conduits shall in all cases be concealed, and all boxes shall be of the flush-mounting type in walls and ceiling. Conduits terminating in the floors should extend 6 inches above the finished floor level.

Conduits and wiring should generally be provided for the following circuits:

(*1*) Projector mechanism
- (*a*) motor
- (*b*) changeover
- (*c*) pilots

(*2*) Projector arcs and spotlights
- (*a*) rheostats, generators, or rectifier

(*3*) Sound equipment
- (*a*) a-c. power supply
- (*b*) loud speaker circuits
- (*c*) amplifier and controls
- (*d*) ground wire

(*4*) Projection room lighting
- (*a*) general (ceiling and Reelites)
- (*b*) emergency

(*5*) Theater auditorium lighting
- (*a*) dimmer
- (*b*) emergency

(*6*) Projector ventilation equipment
- (*a*) normal

(*7*) General ventilation system
- (*a*) normal
- (*b*) emergency

(*8*) Miscellaneous
- (*a*) stage curtain
- (*b*) telephone
- (*c*) buzzer
- (*d*) receptacles

Fig. 2 shows the general arrangement of the equipment requiring these conduits.

(*6.2*) *Projection Arc Supply and Location.*—In cases where the projection arc supply consists of rotating machinery generating acoustical hum or mechanical vibration, acoustical or mechanical insulation will be required. Arc supply equipment should be located in the power equipment room adjacent to the projection room, and at least four feet from any sound amplifier equipment.

(*6.3*) *Power Supply to Equipment.*—Where line-voltage variations are greater than ± 3 per cent, the local power company should be requested to rectify the condition. In cases where it is impossible to maintain a steady line-voltage into the theater, either manually controlled or automatic regulators should be installed.

LIGHTING

(*7.1*) *Projection Room Lighting.*—Approved vapor-proof ceiling fixtures should be installed for general illumination, as indicated in Fig. 2, and arranged to be lighted on either the normal or the emergency lighting circuit.

An individual vapor-proof relight with wire guard shall be located near each projector or spotlamp, as indicated in Fig. 2.

All lights in the projection room and associated rooms, shall be shaded so as to prevent light from entering the auditorium through the ports.

(*7.2*) *Rewind Room.*—An approved vapor-proof ceiling fixture shall be installed for general illumination. A drop-light or wall bracket fixture with approved vapor-proof globe shall be provided

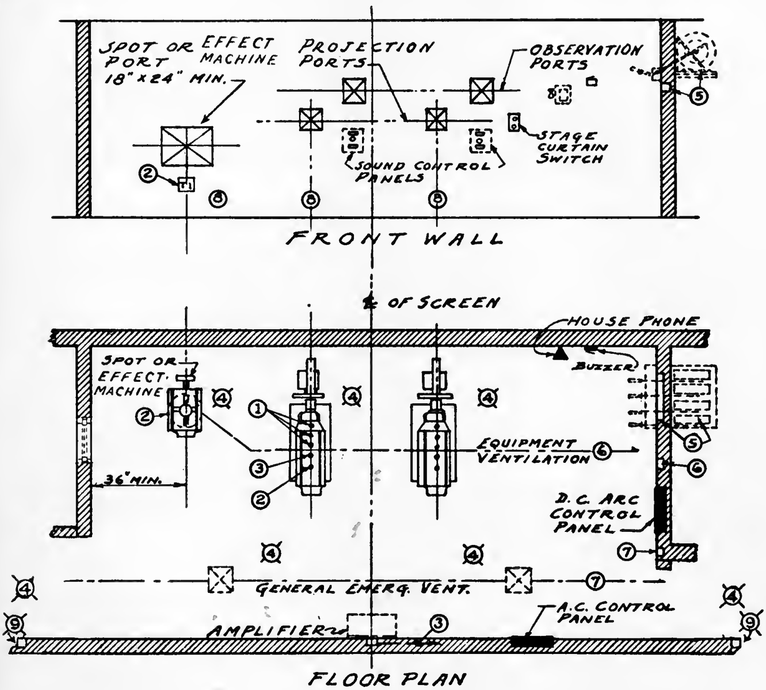


FIG. 2. Projection room equipment, showing conduits, ventilation systems, lights, and switches.

(1) Three conduits in floor to a-c. control panel: for pilot light, changeover and motor feed, for both projectors.
(2) Conduit in floor to d-c. control panel and motor generator: for both projectors and spot (or stereo) via polarized plug-box on front wall of room.
(3) Conduit to pipe ground for each projector, and conduit to loud speakers on stage.
(4) Vapor-proof ceiling fixtures, and vapor-proof Reelites with wire guards for each projector and spot (or stereo).
(5) Dimmer and emergency lighting control.
(6) Projector and spot (or stereo) ventilation system and control switch.
(7) General ventilation system (normal and emergency), with switches inside and outside of doors of projection room.
(8) Wall receptacles.
(9) Wall switches, two-way type, individually controlling each ceiling light fixture from either entrance door.

near or over the rewind table. These lights should be on a separate circuit from the projection room proper.

VENTILATION

(*8.1*) *Arcs or Spotlight.*—In permanent projection rooms, ventilation shall be provided for the arc lamps independently of the general and emergency ventilating system of the room. Each arc lamp housing shall be connected by a flue to a common duct, which duct shall lead directly out of doors and shall contain an exhaust fan or blower having a capacity of at least 50 cubic-feet per minute of air for each arc lamp connected thereto. This exhaust fan or blower shall be electrically connected to the projection room wiring system

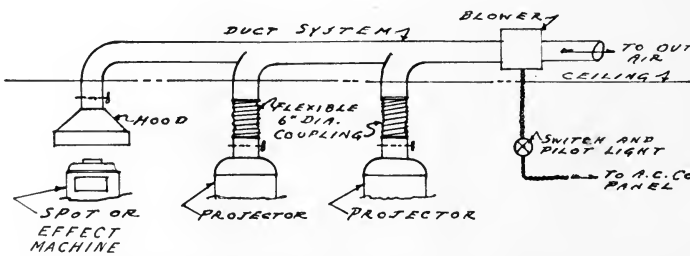


FIG. 3. Equipment ventilation system: blower capacity 400 cu.-ft. per min.; minimum air movement through lamp houses with blower idle, 15 cu.-ft. per min.

and controlled by a separate switch with pilot lamp within the room. There shall at no time be less than 15 cubic-feet of air per minute flowing through each lamp house into an exhaust system connected to the air outside the building. Fig. 3 shows the general arrangement of the system.

(*8.2*) *Projection Room and Rewind Room.*—General ventilation of the projection room and rewind room shall be provided by a duct having outlets at one or more points in the ceiling and leading directly to the outer air. Said duct shall be capable of maintaining a natural circulation of air, without blower or fan, at the rate of not less than 20 cubic-feet per minute. Auxiliary circulation in said duct shall be provided by an exhaust fan or blower having a capacity of not less than 200 cubic-feet per minute for normal circulation and having a rated capacity of not less than 2000 cubic-feet per minute for operation in emergency, *i. e.*, fire. In no case shall the exhaust duct system of

the room be connected with the ventilating system of the building proper. The emergency operation of said fan shall be controlled by a switch (Fig. 6) operated automatically by the shutter control mechanism when the latter is actuated either manually or by melting of the fusible links. This exhaust fan, providing general and emergency ventilation of the projection room and rewind room shall be connected to the emergency lighting circuit of the room, and shall be controlled for normal circulation by a switch and pilot lamp within the room.

The ducts shall be of incombustible material, and shall be kept at least 2 inches from combustible material or separated therefrom by approved non-combustible heat-insulating material, not less than 1 inch thick.

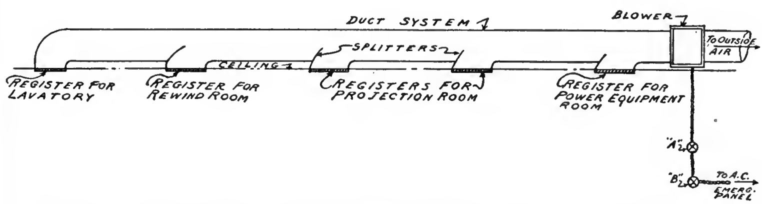


FIG. 4. General and emergency ventilation system: normal blower capacity 200 cu.-ft. per min.; emergency capacity 2000 cu.-ft. per min.

(A) Switch and pilot lamp for normal operation, inside projection room; (B) switch and pilot lamp for emergency operation, outside door of projection room; also connected to port fire-shutter control mechanism.

(Two or more fresh-air intakes required at or near the floor at opposite ends of the room)

Projection rooms and rewind rooms shall have two or more separate fresh air intake ducts at or near the floor and at opposite ends of the room, entirely independent of and in no way connected to the exhaust ducts of the room. Such air intake ducts may be connected into the main ventilating system of the building. (See Fig. 4 for general arrangement.)

PORT SHUTTERS

(9.1) Construction.—Each port opening shall be provided with a gravity shutter of approved construction. Said shutter and guides shall be made of not less than 10-gauge iron, and the shutter should set into the guides not less than 1 inch at sides and bottom and overlap the top of the port opening by not less than 1 inch, when

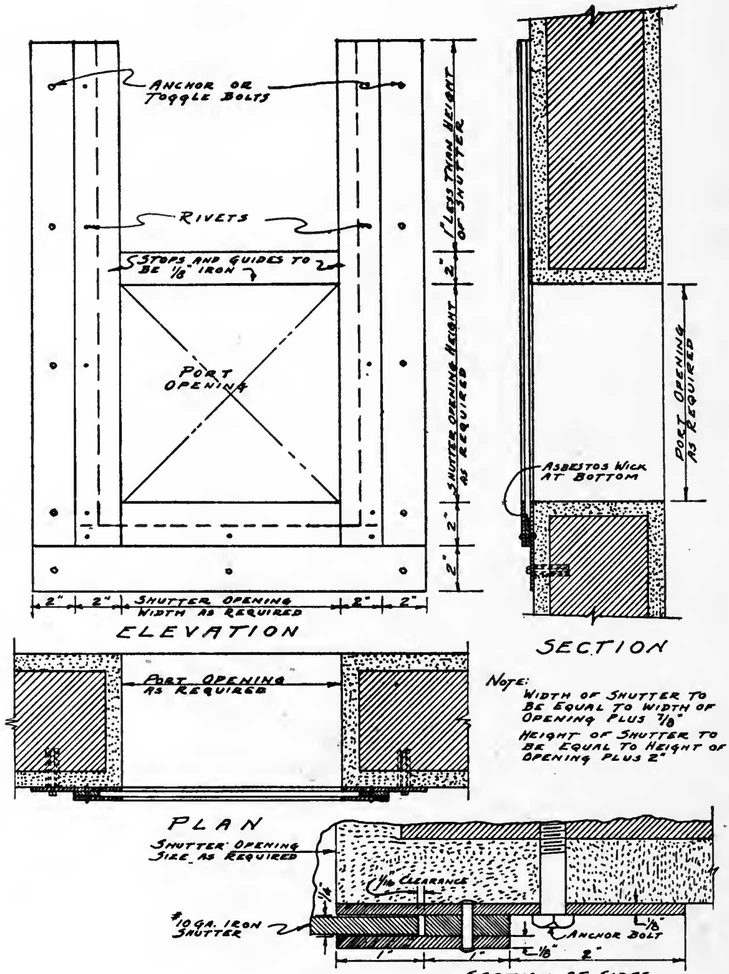


FIG. 5. Example of port shutter construction. Although this construction shows rivets, spot welding is preferable.

closed. Guide parts should preferably be welded (see Fig. 5). Shutters shall be suspended, arranged, and inter-connected, so that all port shutters will close upon the operating of some suitable fusible or mechanical releasing device, designed to operate automatically in case of fire or other contingency requiring immediate and complete isolation of the contents of the projection room from other portions of the building. Each shutter shall have its own individual fusible link directly above it. A fusible link shall be located also above each upper projector magazine, which upon operating shall close all the shutters. There shall also be provided suitable means for manually closing all shutters simultaneously from any

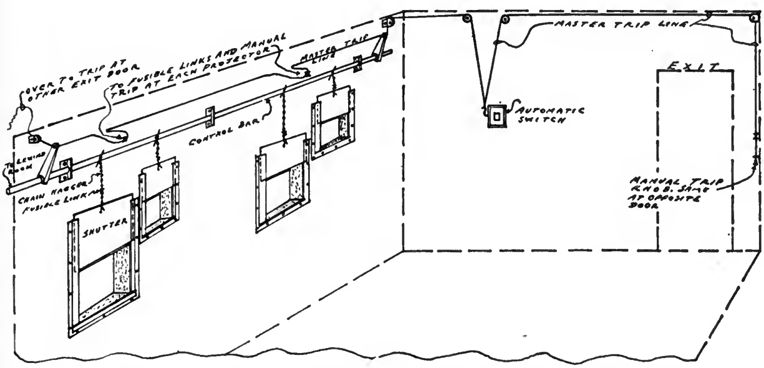


FIG. 6. One of many possible arrangements of the port fire-shutter control. The automatic switch operates the exhaust fan and emergency lights

projector head and from a point near each door within the projection room. Shutters shall be free-acting. Shutters on openings not in use shall always be kept closed. Fig. 6 indicates one of many ways of arranging the shutter control system. All large shutters such as for spotlamps and special-effect machines (when used) shall be provided with weights to facilitate operating them manually.

(*9.2*) *Noise Transmission.*—The Committee recommends the use of means other than glass in projection ports to prevent transmission of noise from the projector room to the auditorium, such as reducing the free aperture of the port to the minimum size necessary for projection by use of fire-proof sound baffles.

Observation ports shall be fitted with a good grade of plate glass set in a metal frame at an angle to the vertical to avoid direct re-

flection, and easily removable from the inside of the projection room for cleaning. The purpose of this glass is to prevent transmission of noise into the auditorium.

HEATING

(*10.1*) *General.*—Proper provision shall be made for heating the projection room. The same facilities used for heating the theater should be extended to the projection room.

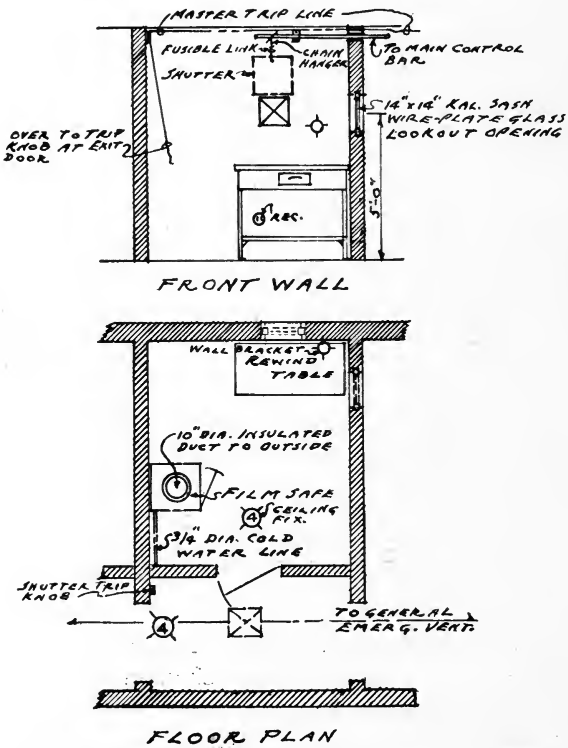


FIG. 7. Rewind room layout, showing required equipment.

PAINTING AND FLOOR COVERING

(*11.1*) *Painting.*—The color of the walls shall be olive green to the height of the acoustic plaster. The latter should be painted in accordance with the instructions of the manufacturer of the material, preferably a dull buff color. The ceiling should likewise be painted white. All iron work of the projection ports shall be covered with at least two coats of flat black paint.

(*11.2*) *Floor Covering.*—Where local regulations permit, the floors of the projection room and rewind room should be covered with a good grade of battleship linoleum cemented to the floor. The floor covering should be laid before the equipment is installed.

EQUIPMENT

(*12.1*) *Projection Room.*—All equipment to be used in the projection room should be of approved type, including the projectors, arc lamps, sound equipment, etc.

All shelves, furniture, and fixtures within the projection suite shall be constructed of metal or other incombustible material. A metal container for hot carbon stubs shall be provided.

Adequate locker space shall also be provided.

(*12.2*) *Rewind Room.*—In the rewind room shall be provided an approved fire-proof film safe or cabinet, a table, approved rewind equipment, a splicer, and approved scrap film can (Fig. 7).

The film safe or cabinet shall be capable of holding 25,000 feet of 35-mm. film.

All tables and racks and all furniture shall be of metal or other non-combustible material and should be kept at least 4 inches away from any radiator or heating apparatus. Tables shall not be provided with racks or shelves beneath them whereon may be kept film or other materials.

The scrap film can shall have an automatic-closing hinged cover and so arranged that the scrap film is kept under water at all times.

Quantities of collodion, amyl acetate, or other similar inflammable cements or liquids kept in the rewind room for the purpose of splicing film, shall not exceed $^1/_2$ pint.

No stock of inflammable materials of any sort whatsoever shall be permitted within the rewind suite except as specifically mentioned herein.

All splices of film shall be made with approved mechanical cutting and splicing machines. No hand cutting or splicing shall be permitted.

Film shall be kept in the film cabinets at all times except when being projected or rewound. Any films in addition to those used for the current showing or in excess of that permitted by local authorities shall be kept in their original shipping containers.

(*12.3*) *Fire Extinguishing Equipment.*—Local authorities having

jurisdiction with regard to fire extinguishing equipment should be consulted regarding the proper types, numbers, and locations.

MISCELLANEOUS

(*13.1*) "No smoking" signs should be posted in prominent places and matches should not be carried by any employee.

(*13.2*) *Operation.*—Motion picture projectors shall be operated by and shall be in charge of qualified projectionists who shall not be minors. The projectionist should be stationed constantly at the operating side of the projector while it is in operation. A proper factor of safety in operation, as well as avoidance of imperfect operation of projection equipment, or unjustified interruptions of service can be attained only by having an adequate personnel in the projection room.

(*13.3*) *Action in Case of Fire.*—In the event of film fire in the projector or elsewhere in a projection or rewind room, the projectionist shall immediately shut down the projector and arc lamps, operate the port shutter release at the point nearest him, turn on the auditorium lights, leave the projection room immediately, and notify the manager of the theater or building. An automatic switch is recommended for the electrical operations mentioned.

SUB-COMMITTEE ON PROJECTION ROOM PLANS

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PROPOSED REVISION OF REGULATIONS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS FOR NITROCELLULOSE MOTION PICTURE FILM AS PERTAINING TO PROJECTION ROOMS*

For a long time it has been recognized that numerous conflicts existed between the provisions of the *Regulations of the National Board of Fire Underwriters for Nitrocellulose Motion Picture Film* and the *National Electric Code*. In addition, when the revision of the Projection Room Plans issued by the Projection Practice Committee in 1935[1] was brought to the attention of the National Fire Protection Association, a number of conflicts between the *Plans* and the *Regula-*

* Readers of the JOURNAL are requested to transmit their comments concerning these revisions to the General Office of the Society.

tions were discovered. In view of this confusion, steps were taken by the NFPA to make their Committee on Hazardous Chemicals and Explosives, authors of the *Regulations*, responsible for the preparation of all material relating to motion picture fire prevention. All such material to appear in future issues of the National Electric Code will be taken from the revised *Regulations*.

To assist in this work, the Projection Practice Committee of the SMPE agreed to submit its recommendations for revising the portions of the *Regulations* pertaining to projection rooms, with respect to which most of the conflicts have occurred.

Such recommendations have been prepared and have been submitted to the NFPA Committee on Hazardous Chemicals and Explosives, of which Mr. A. H. Nuckolls is Chairman. A special subcommittee has been appointed by the Committee on Hazardous Chemicals and Explosives for considering these recommendations. The Chairman of this sub-committee is Mr. George W. Booth, Chief Engineer of the National Board of Fire Underwriters, and the personnel of the sub-committee includes engineers long experienced in the field of fire prevention. The Chairman of the Sub-Committee on Projection Room Fire Regulations represents the Projection Practice Committee on the NFPA sub-committee.

The proposed revisions are published herewith for the purpose of soliciting expressions of opinion concerning them from the motion picture industry.

In the following proposals, sections of the *Regulations* pertaining to exchanges, studios, storage vaults, *etc.*, not dealing with projection or projection rooms, were not considered. Where no change is proposed, the section is marked "*Unchanged*"; added words or clauses are underlined; sections completely rewritten are marked "*Rewritten*"; proposed new sections are marked "*New*"; sections recommended for deletion are marked "*Deleted.*"

Attention should be called to one very important departure in these proposals: In the original *Regulations*, structural details of permanent projection rooms and temporary projection booths were grouped together in the same sections and sub-sections (Sec. *191*). The Projection Practice Committee deemed it advisable to remove from Section *191* all references to temporary projection booths; and since it is recommended that the existing Section *192* be deleted from the *Regulations*, the material pertaining to temporary projection booths may be assigned to this Section *192*.

PART I

GENERAL PROVISIONS REGARDING THE STORAGE AND HANDLING OF MOTION PICTURE FILM

Section 11—Construction and Arrangement of Buildings

(*111*) (*Unchanged*) Motion picture film should preferably be stored or handled only in buildings of fire-proof construction.

(*114*) *Exits.*—It is essential that all rooms in which film is handled be provided with adequate aisle space, *not less than 30 inches clear, wherever walking is necessary between any two pieces of equipment, so as to provide* safe means of egress. Rooms in which film is handled and in which more than two persons work shall have two or more exits, remote from each other. Every exit shall be marked *Exit* in letters not less than 6 inches high, or by an illuminated sign with letters of the same height

(*115*) *Vents.*—All new buildings erected to be used as, and all existing buildings remodeled for, film occupancies, *except as related to projection rooms, rewind rooms, and rooms associated therewith,* shall be provided in every room, where film is to be stored or handled, with vents that will open automatically in case of fire. These should be of ample size; they may be in the form of automatic skylights or automatic-opening window sash. All rooms, except as aforementioned, in which film is stored or handled in existing buildings, shall be provided with such vents wherever practicable.

(*117*) (*Unchanged*) *Tables and Racks.*—Tables and racks used in connection with the handling of film (joining, inspection, and assembling tables, for example) shall be of metal or other non-combustible material. They should be kept at least 4 inches away from any radiators or heating apparatus. Tables shall not be provided with racks or shelves underneath them that might be used for keeping film or other materials.

Section 12—Electrical Equipment

(*121*) (*Unchanged*) Artificial illumination in any room where film is handled or stored shall be restricted to incandescent electric lights, except that arc lights or other forms of electric lights may be used in studios.

(*122*) (*Unchanged*) All electrical wiring and equipment shall conform to the *National Electrical Code*. Wiring shall be in metal conduit, and fuses shall be enclosed.

(*123*) (*Unchanged*) Lighting fixtures shall be firmly fixed in place, and lights shall be protected by vapor-proof globes. All lights shall be equipped with keyless sockets and operated by wall switches.

(*125*) (*Rewritten*) Portable electric lamps on extension cords are prohibited in any room in which film is handled or stored, except that portable electric lamps provided with approved keyless sockets and metal protective lamp guards and having service cords of types *S* or *SJ* with twist-lock plugs are permissible in projection rooms.

(*126*) (*Unchanged*) Motors shall be of the non-sparking type, or shall be of an enclosed type, so arranged as to minimize the danger of sparks.

(*127*) Motion picture projectors *and associated electrical equipment* shall be of approved type and safeguarded in accordance with the requirements of the *National Electric Code*, Article *540*.

(*128*) (*New Section*) Motor-generator sets, transformers, rectifiers, rheostats, and similar equipment, for the supply or control of current to arc lamps on motion picture projectors, shall if practicable be located in a room separate from the projection room or booth. Such separate room shall be suitably ventilated. No rheostats exceeding 30-ampere capacity shall be installed in a projection room or booth.

Motor-generator sets shall have the commutator end or ends protected as provided in the *National Electric Code*, Section *5310*. Rheostats shall be constructed and installed as provided by the *National Electric Code*, Article *470*.

When motor-generators, transformers, rectifiers, and similar equipment are installed in the projection room or booth they shall be so located and guarded that arcs or sparks caused thereby can not come into contact with film, and shall be so located as to provide at least 30 inches of clear aisle space between any two pieces of equipment where walking is necessary. Rheostats for arc lamps (not exceeding 30-ampere capacity) when installed in the projection room or booth shall be installed near the ceiling upon suitably supported heavy metal shelves provided with metal pans having upturned sides. The rheostats shall be electrically and heat insulated therefrom.

Section 13—Heating Equipment

(*131*) (*Unchanged*) Artificial heating in any building or room, other than a vault, in which motion picture film is used, handled, or

stored, shall be restricted to steam not exceeding 15 pounds' pressure or hot water, provided, however, that this shall not be construed as prohibiting the installation of an indirect system employing high-pressure steam when the radiators or heating coils of such system are not located in the room or rooms to be heated. Heat generating apparatus shall be in a separate room.

Note.—Ordinary hot-air furnaces are prohibited. Gas, oil, and electric heaters are prohibited in rooms where film is handled or stored.

(*132*) (*Unchanged*) All steam pipes within 6 feet of the floor, and where passing through partitions or racks or near woodwork, shall be covered with approved pipe covering. All radiators, heating coils, and pipes and returns that are near the floor or are so located as to permit any combustible material, waste, or dirt to come in contact therewith shall be guarded and protected by means of $^1/_4$-inch mesh galvanized steel wire cloth No. 20 B. & S. gauge, or by its equivalent. The bottoms of such guards shall be arranged so as to lift up for cleaning purposes and the tops to slope so that guards can not be used as shelves. Guards shall be so constructed that no film can come within 4 inches of the heating surface, and shall be made with a substantial metal framework that will prevent the wire mesh from being forced against the radiator or pipes.

Section 14—Sprinklers and Other Fire Protection Appliances

Note.—See Sub-Section *174* regarding sprinklers in film vaults.

(*141*) (*Unchanged*) Every room in which film is stored or handled in quantities greater than 50 pounds (10 standard rolls), except in motion picture projection booths or rooms and rewinding rooms connected therewith, shall be equipped with an approved system of automatic sprinklers. Buildings or sections of buildings used as exchanges, laboratories, or studios shall be equipped with automatic sprinklers, as provided under Sub-Sections *221*, *231*, and *241*. All buildings used for the storage or handling of film should be completely equipped with automatic sprinklers.

(*144*) Every room in which film is stored or handled, except film vaults and *projection rooms*, shall be provided with first-aid fire appliances of types using water or water solutions.

Note.—Small hose equipment is recommended, and the following types of extinguishers are considered suitable: soda acid, calcium chloride, pump tank, water pails, and loaded stream.

See Regulations on First-Aid Fire Appliances, and Standpipe and Hose Systems.

Section 15—Storage of Film

(*151*) (*Unchanged*) The storage of motion picture film, not in process or being worked upon, and except as hereinafter specifically provided shall be in accordance with the following rules:

(*a*) Except as provided in paragraph (*b*):

(*1*) Amounts in excess of 25 pounds (5 standard rolls but not in excess of 1000 pounds (200 standard rolls) shall be kept in approved cabinets if not in vaults;

(*2*) Amounts in excess of 1000 pounds shall be kept in vaults;

(*3*) Storage for any considerable length of time should be in vaults only.

(*b*) Unexposed film enclosed in the original shipping cases, conforming to I. C. C. regulation with each roll in a separate container, shall be kept in a sprinkler room, and if over 5 cases aggregating in excess of 750 pounds (150 standard rolls), shall be kept in a sprinklered room used for no other purpose.

Section 18—Handling of Film

(*181*) (*Unchanged*) Film shall be in containers. All film shall be kept in closed containers except during the actual time it is being worked upon or examined. This is very essential from the standpoint of fire hazard and safety to life. I. C. C. shipping containers and individual containers for each roll of film with proper corrugations on each side are recommended.

(*182*) (*Unchanged*) Film shall not be placed or kept under benches, tables, or other surfaces that would shield it from the discharge of sprinklers.

(*183*) (*Unchanged*) *Scrap Film.—Scrap film* shall be kept separate from waste paper and other rubbish, and shall be kept under water at all times. It shall be collected from work rooms at least once daily, and removed to a room used for no other purpose, where it shall be kept under water in steel drums with tight covers. These drums shall be disposed of at frequent intervals. Discarded film in full or part rolls shall be kept in vaults. Scrap film shall not be baled or burned.

Note.—Motion picture film in the form of clippings and short lengths is in a very hazardous form. Safe precautions in the handling of such scraps are most essential. Baling and burning of film are processes offering a distinct fire hazard. Sending film to a central reclaiming plant is recommended in lieu of burning.

Section 19—Motion Picture Projection and Special Processes

(*191*) (*Rewritten*) *Permanent Enclosures for Motion Picture Projectors.*—Enclosures are classified into two types, permanent and temporary. The permanent type of enclosure in permanent installations

are known as *Projection Rooms;* the temporary type of enclosure as *Temporary Projection Booths.* (See Sec. *192.*)

(*a*) *Projection Rooms.*—Motion picture projectors using nitrocellulose film in structures or buildings definitely intended for motion picture exhibition purposes shall be operated or set up for operation only within an approved projection room. For one machine the projection room shall be not less than 8 feet wide by 10 feet deep by 8 feet high; and for two machines, not less than 14 feet wide by 10 feet deep by 8 feet high. Not less than 30 inches of clear aisle space, where walking is necessary, shall be allowed between any two pieces of equipment or between projectors.

Note.—Motion picture projectors capable of operating *only* with 35-mm. cellulose acetate film (*i. e.,* slow-burning or non-inflammable film) may be operated without an enclosure but only by permission of local authorities having jurisdiction.

(*b*) The projection room walls shall be built of brick, tile, or plaster blocks plastered on the inside with $^3/_4$ inch of cement plaster, or all concrete. The core of the wall shall be not less than 4 inches thick. When plaster block is used it shall be supported upon a steel framework.

The ceiling shall be constructed of 4-inch concrete slabs or precast concrete; it may be constructed of 3-inch plaster blocks supported by a steel structure and plastered on the inside with $^3/_4$ inch of cement plaster.

Note.—Approved fire-proof acoustic material may be used on ceiling and walls above a height of 4 feet from the floor.

The floor shall be a reënforced concrete slab not less than 4 inches thick.

All projection room construction shall be supported upon or hung from fire-proof structural steel or masonry.

All exposed steel shall be covered with a minimum of $1^1/_2$ inches of cement plaster.

(*c*) Two doors shall be provided, one at each end of the projection room, each at least 30 inches wide by 6 feet high. They shall be of the approved one-hour fire-test type and shall be arranged so as to close automatically, swinging outwardly, and shall be kept closed at all times when not used for egress or ingress. It shall be possible at all times to open either door from the inside merely by pushing it. Door jams shall be of steel.

These exits shall be provided strictly in accordance with regula-

tions of local authorities having jurisdiction, particularly with reference to other sizes and locations. At least one of these exits should be of the conventional stairway type, with risers not in excess of 9 inches and a minimum tread to each step of not less than 7 inches. Stairs shall be sufficiently wide to permit easy egress.

(*d*) Two orifices or openings for each motion picture projector or stereopticon shall be provided: one for the projectionist's view (observation port) shall be not larger than 200 square-inches, and the other, through which the picture is projected (projection port) shall be not larger than 120 square-inches. Where separate spotlight or floodlight machines are installed in the same projection room with motion picture projectors, not more than one port opening for each such machine shall be provided for both the operator's view and for the projection of the light, but two or more machines may be operated through the same port opening. Such port openings shall be as small as practicable, and in any case shall not exceed $7^1/_2$ square-feet in area.

(*e*) Each port opening shall be provided with a gravity shutter of approved construction. Said shutter and guides shall be made of not less than 10-gauge iron, and the shutter shall set into the guides not less than 1 inch at sides and bottom and overlap the top of the port opening by not less than 1 inch, when closed. (See Fig. 5.) Shutters shall be suspended, arranged, and interconnected so that all port shutters will close upon the operating of some suitable fusible or mechanical releasing device, designed to operate automatically in case of fire or other contingency requiring immediate and complete isolation of the contents of the projection room from other portions of the building. Each shutter shall have its own individual fusible link directly above it. A fusible link shall be located also above each upper projector magazine, which upon operating shall close all the shutters. There shall also be provided suitable means for manually closing all shutters simultaneously from any projector head and from a point near either door within the projection room. Shutters shall be free-acting and regularly tested. Shutters on openings not in use shall always be kept closed.

(*f*) All shelves, furniture, and fixtures within the projection room shall be constructed of metal or other incombustible material. Tables shall be in accordance with Section *117*. No stock of inflammable material of any sort whatever shall be permitted or allowed to be within the projection room, except what is required for the regular

and immediate operation of the equipment, the films used in the operation of the machines, and film cement. (See Sec. *214.*)

(*g*) In permanent projection rooms, ventilation shall be provided for the arc lamps independently of the general and emergency ventilating system of the room. Each projector arc lamp housing shall be connected by a flue to a common duct, which duct shall lead directly out of doors and shall contain an exhaust fan or blower having a capacity of at least 50 cubic-feet per minute of air for each projector arc lamp connected thereto. This exhaust fan or blower shall be electrically connected to the projection room wiring system and controlled by a switch with pilot lamp within the room. There shall at no time be less than 15 cubic-feet of air per minute flowing through each lamp house into the exhaust system connected to the air outside the building.

General ventilation of the projection room shall be provided by a duct having outlets at one or more points in the ceiling and leading directly to the outer air. Said duct shall be capable of maintaining a natural circulation of air, without blower or fan, at a rate of not less than 20 cubic-feet per minute. Auxiliary circulation in said duct shall be provided by an exhaust fan or blower having a capacity of not less than 200 cubic-feet per minute for normal circulation and having a rated capacity of not less than 2000 cubic-feet per minute for operation in emergency, *i. e.*, fire. In no case shall the exhaust duct system of the room be connected with the ventilating system of the building proper. The emergency operation of said fan shall be controlled by a switch operated automatically by the shutter control mechanism when the latter is operated either manually or by melting of the fusible links. This exhaust fan, providing general and emergency ventilation of the projection room, shall be connected to the emergency lighting circuit of the room, and shall be controlled for normal circulation by a switch and pilot lamp within the room.

The ducts shall be of incombustible material, and shall be kept at least 2 inches from combustible material or separated therefrom by approved non-combustible heat-insulating material not less than 1 inch thick.

Projection rooms shall have two or more separate fresh-air intake ducts at or near the floor and at opposite ends of the room, entirely independent of and in no way connected to the exhaust ducts of the room. Such air intake ducts may be connected into the main ventilating system of the building.

(*192*) (*Delete*) Not more than five motion picture projectors shall be located in one room, unless the projectors are of a type using incandescent electric lights of not over 25-watt size, when not more than ten projectors shall be located in one room.

(*192*) (*New Section*) *Temporary Projection Booth.*—Motion picture projectors using nitrocellulose film, when used in other places than in permanent enclosures, (*i. e.*, in *projection rooms*), shall be set up and operated in a temporary enclosure known as a *Temporary Projection Booth.* However, such temporary projection booths shall be installed only by permission of local authorities having jurisdiction, and then only for a limited number of exhibitions of motion pictures in a structure or building suitable therefor and not regularly licensed for such purpose. In no case shall temporary projection booths be allowed as part of the structures or buildings definitely intended for motion picture exhibition purposes.

(*a*) Temporary projection booths shall conform to Section *191* (*a*) with regard to dimensions.

(*b*) The sides, walls, and ceiling shall be constructed of $^1/_4$-inch hard sheet asbestos board, and the floor of $^3/_8$-inch hard sheet asbestos board, the whole securely riveted or bolted to a rigid metal frame of not less than $1^1/_4$ by $1^1/_4$ by $^1/_4$-inch angle-irons properly braced. The sheet asbestos boards shall sheath the entire interior of the frame work, and no metal frame supports shall be allowed to remain exposed within the enclosure. All joints shall be made as air-tight as possible to prevent the discharge of smoke.

(*c*) One entrance door shall be provided which shall conform to the requirements for the main entrance door of Section *191* (*c*) with the following exceptions:

(*1*) the fire resistance of the door shall be equivalent to the fire resistance of the rest of the construction, and

(*2*) clear aisle space or passageway shall be provided around the projection booth and from the entrance door thereof to the nearest exit of the structure or building in which the projection booth is installed.

(*d*) Observation and projection ports shall conform to the specifications of Section *191* (*d*).

(*e*) Port shutters shall conform to the requirements of Section *191*.

(*f*) All shelves, furniture, and fixtures within the projection room shall conform to the requirements of Section *191*(*f*). There shall additionally be provided an approved can for scrap film, having an

automatically closing hinged cover; also a similar container for receiving hot carbon stubs, said container to be partly filled with sand.

(*g*) The ventilation system of the temporary projection booth shall conform to all the requirements of Section *191*(*g*).

(*h*) Rewinding film in temporary projection booths, as in permanent, shall be done in accordance with Section *212*(*c*).

(*i*) Quantity of film contained within a temporary projection booth shall be in accordance with Sub-Section *213*(*a*)(*3*).

(*j*) Projection equipment in temporary projection rooms shall be operated in accordance with Section *213*.

(*193*) *Processing Film.*—The processing of film, as cleaning, polishing, buffing, and other special treatment, shall not be done in rooms *where* other operations *are performed, except that in the case of motion picture theaters, such processing or cleaning of film shall be done in the rewind room. See Section 212* (*a*).

Special processes for treating film shall be provided with such proper safeguards as are necessary for protection against the hazards involved. The inspection department having jurisdiction shall be consulted in regard to the protection needed.

(*196*) (*Unchanged*) *Film Cement.*—Compounds of all collodion, amyl acetate, or similarly inflammable cements shall not be kept in the rooms where they are used, in quantities greater than 1 quart; and such material in excess of this quantity shall be kept in a vault. The use of these materials in motion picture theaters and other special occupancies is covered in Sub-Section *214*.

(*197*) (*Unchanged*) *Smoking.*—Smoking, except in rooms especially provided for the purpose, should be prohibited in any establishment handling or storing film, and conspicuous *No Smoking* signs should be posted in prominent places. Matches should not be carried by any employee.

PART II

SPECIAL PROVISIONS FOR SPECIAL OCCUPANCIES

Section 21—Motion Picture Theaters and Other Occupancies in Which the Principal Use of Film Is in Motion Picture Projection

(*211*) *Enclosure for Projectors.*—Motion picture projectors shall be installed in a projection room in accordance with Sub-Section *191*.

(*212*) (*Rewritten*) *Rewinding.*—(*a*) Rewinding film is permitted in permanent projection rooms (but not recommended) when pro-

jectors and lamps are not in use. There shall be provided an approved can for scrap film, having an automatically closing hinged cover. When rewind table and approved film cabinets are in the projection room, such table and cabinets must be at least 30 inches from the rear of any projector.

(*b*) Where rewinding of film in permanent installations is done in a separate room, at approved location adjacent to or near the projection room, such rewinding rooms shall be of construction similar to that of the permanent projection room, as specified in Sub-Section *191*. Such room shall be not less than 80 square-feet in area and shall have clear walking spaces not less than 30 inches wide. The ventilating system shall be connected directly to the outside air and shall conform, as to capacity, to the specifications of Sub-Section *191* (*g*), and may be combined with the general ventilation system of the projection room.

(*c*) Rewinding film shall not be done in temporary projection booths except when projectors and lamps are not in use and are cool.

(*213*) (*Unchanged*) *Care and Use of Film.*—Motion picture film used in connection with the projection of motion pictures (as in theaters, motion picture theaters, screening or projection rooms, sound recording studios, and motion picture titling studios) shall be limited and kept as follows:

(*a*) (*Rewritten*) The quantity of film in any projection room or booth or rewinding room shall be limited to that given below:

(*1*) (*Rewritten*) In a projection room, constructed to conform to Section *191:* not exceeding 125 pounds (25,000 feet of 35-mm. film);

(*2*) (*Unchanged*) In a rewinding room constructed and vented to conform to Section *191* and Sub-Section *212* (*b*) and separated from the projection room with openings thereto protected with approved fire doors: not exceeding 125 pounds (25,000 feet of 35-mm. film);

(*3*) (*Rewritten*) In a temporary projection booth, constructed to conform to Section *192:* not exceeding 75 pounds (15 feet of 35-mm. film);

(*4*) (*Rewritten*) In a special room constructed and vented as required for rewinding rooms (see Sub-Sec. *212*), when approved by the inspection department having jurisdiction: not exceeding 125 pounds (25,000 feet of 35-mm. film) may be kept in lieu of the amount permitted in either the projection room or the rewinding room. The total quantity in the three rooms shall not exceed 250 pounds (50,000 feet of 35-mm. film).

(*b*) The above quantities of film shall be kept as follows:

(*1*) Up to 40 pounds (8000 feet of 35-mm. film) of film may be kept in Interstate Commerce Commission shipping containers, or approved cabinet in each room;

(*2*) If the amount of film on hand exceeds 40 pounds, an approved cabinet shall be provided, in which the amount of film in excess of 40 pounds shall be kept.

(*214*) (*Unchanged*) No collodion, amyl acetate, or other similar inflammable cement or liquid in quantities greater than $^1/_2$ pint shall be kept in the projection room or rewinding room.

(*215*) (*New Section*) All splices of film shall be made on approved mechanical cutting and splicing machines in approved manner. No hand cutting or splicing shall be permitted.

(*216*) (*Unchanged*) *Location.*—The number and location of motion picture projection rooms or booths in any non-sprinklered building shall be subject to the approval of the inspection department having jurisdiction.

(*217*) (*New Section*) *Operation.*—Motion picture projectors in permanent or temporary projection rooms shall be operated by and shall be in charge of qualified projectionists, who shall not be minors.

(*218*) (*New Section*) *Action in Case of Fire.*—In the event of film fire in the projector or elsewhere in a projection or rewind room, the projectionist shall immediately shut down the projection machine and arc lamp, operate the port shutter release at the nearest point to him, turn on the auditorium lights, leave the projection room promptly, and notify the manager of the theater or building.

REFERENCE

[1] Report of Projection Practice Committee, *J. Soc. Mot. Pict. Eng.*, **XXV** (Oct., 1935), No. 4, p. 341.

SUB-COMMITTEE ON FIRE REGULATIONS

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NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus and materials are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A NEW SOUND SYSTEM*

G. FRIEDL, JR.**

Recent improvements in film recording technic have made practically obsolete the older types of theater reproducing equipments that do not employ high-power amplifiers, rotary stabilizer sound mechanisms, and multicellular loud speakers. Since the commercial introduction of sound motion pictures, various equipment changes have been introduced, mostly as modification to existing equipment, making the original apparatus more suitable for the particular application of reproducing sound in motion picture theaters. With such modernization, however, it is often difficult to effect an overall improvement without making radical and expensive changes in all the components of the system. For example, when the frequency range of the amplifier is extended it is necessary to modify the loud speaker system so that it will adequately transform and distribute the increased range, and it is also necessary to modify the sound mechanism or reproducer set to insure uniform film movement at the scanning beam so that high frequencies will be reproduced without harshness or flutter. Such changes, when carried through consistently and effectively, become very expensive, and a point is reached where it is economically impracticable to attempt further "patching-up" of the system. Complete replacement is therefore more desirable. This is of significance to the small theater owner whose equipment is not adequate to reproduce properly the pictures now being produced by Hollywood. Recognizing the importance of making available reasonably priced reproducing equipment that will provide sufficient volume and life-like reproduction equivalent to that generally found only in the largest theaters, this new sound system has been produced.

DESIGN REQUIREMENTS

General.—The Simplex Sound System is built to present-day requirements determined after a survey made in coöperation with persons who are conversant with the actual operating conditions of the theater—it is built for theater usage,

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received September 20, 1938.

** International Projector Corp., New York, N. Y.

and is not an adaptation of apparatus built for other fields. High quality dependability, easy operation, economical maintenance, and installation are paramount features. The practice of making equipment of sub-standard quality in order to place it in a suitable competitive price class for the small theater is avoided. All the features that contribute to sound reproduction of the highest quality are included in every system. The variables that distinguish one size of system from another are the number of power amplifiers operating in parallel to provide the proper output, and the number and types of loud speakers to provide adequate capacity and distribution.

In analyzing the requirements of film reproducing systems for the theater, the equipment has been divided into four groups, *viz.*, the sound mechanism equipment, control equipment, power amplifier equipment, and loud speaker equipment, as shown in Fig. 1.

	Sound Mechanism Equipment	Control Equipment	Power Amplifier Equipment	Loud Speaker Equipment
Constants	35-Mm. film 90 Feet/minute Standard, push-pull Dual channel 2–3 Sec. pick-up ±0.15% total flutter	Change-over 2000-Ft. reels Volume control at each machine	1% Total harmonic at 50 cycles −35 Db. noise level	Two-way system 400-Cycle cross-over Multicellular horn
Variables	None	None	Power	Power, Coverage
Small (1000 Seats) (84%)	Identical throughout ↓	Identical throughout ↓	*a* (15 watt)	*A* *B*
Medium (2000 Seats) (13%)			2*a* (30 watt)	2*A* 2*B*
Large (4000 Seats) (3%)			4*a* (60 watt)	2*C* 4*D*

FIG. 1. Analysis of design requirements.

The tabulation is divided into three horizontal sections representing the small, the medium, and the large theaters, and at the head of each equipment group are shown the salient requirements or "constants" of design. Under "Sound Mechanism," regardless of the size of theater, the equipment is to operate with 35-mm. film running 90 feet a minute; it is to reproduce standard track and be adaptable to push-pull and "dual track" reproduction with simple modification; it must come up to speed in 2 to 3 seconds, and the flutter and weave should be held to the same low limits. There are no "variables"; that is, there is no reason to relax on any of the requirements for smaller theaters. Thus one policy of the design is established—the sound mechanism shall be identical for the small, the medium, and the large systems.

The requirements of the "Control Equipment" include the apparatus for volume control and change-over. With the standardization of 2000-ft. release print reels the same number of change-overs is required in the small theater as in the large theater, and the change-over should be made with the same accuracy and facility. Convenient volume control should be provided at each machine. These are the "constants" of the equipment design; there are no "variables." Thus the second policy of the design is established—the control equipment shall be identical for the small, medium, and large systems.

At this point the question may be raised, "What are the justifiable differences between small, medium, and large systems?" Technically speaking there are none. It would be best to have all systems alike because the more undistorted power available, the greater is the factor of safety against overload and the more adapt-

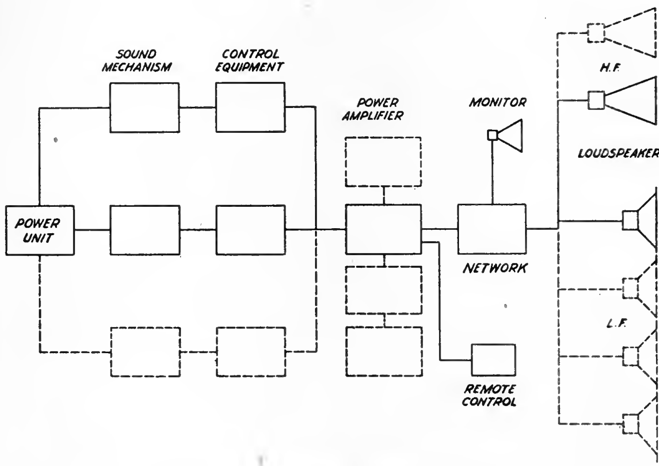
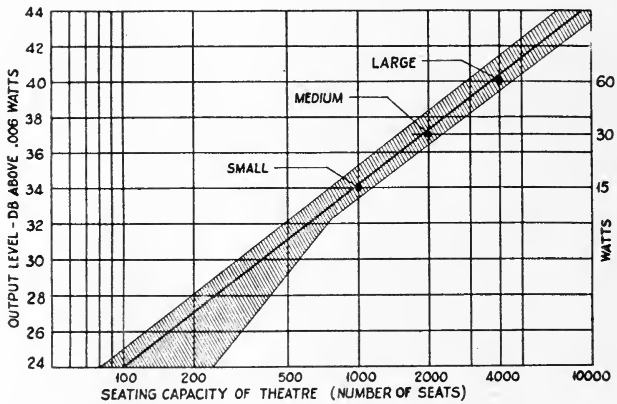


FIG. 2. Schematic diagram of system.

able will be the system to future developments. But due to commercial considerations we must provide a group of systems offering economical combinations for each size of theater with high-power systems for the small theaters as well as the larger ones. Thus we generally establish the main "variable" of design—power. This is a quantitative variable only; qualitatively the power for all systems must be the same. The quality in the small theater, so far as the amplifier is concerned, should be just as good as in the larger theaters. Referring again to Fig. 1 it will be noted under "Power Amplifier Equipment" that the requirements of permissible harmonic distortion, noise level, and hum content are the "constants" of design. The "variable," power, is indicated as a for the small system, $2a$ for the medium system, and $4a$ for the large system. To concentrate on the development of an amplifier that would meet these requirements, a single amplifier was designed for use on a unit basis—that is, one unit for the small system, two units in parallel for the medium system, and four units in parallel for the large system, all of the same

quality. The total harmonic distortion is less than 1 per cent with the amplifier delivering rated power at 50 cycles.

Under "Loud Speaker Equipment," power is again the variable factor. The main interest is to provide loud speakers that will handle the power delivered to them by the amplifiers and convert it into acoustical energy efficiently, thus pro-



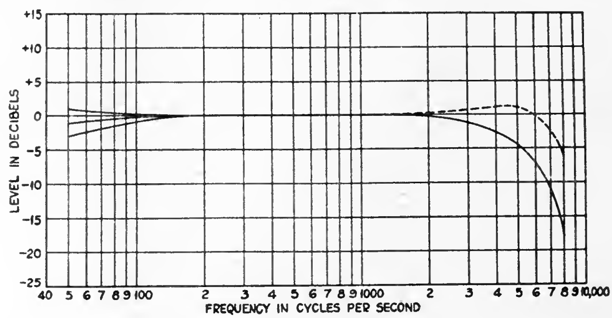


FIG. 3 (*Upper*) Recommended amplifier output in electrical watts in terms of seating capacity of theater (Research Council, Academy of Motion Picture Arts & Sciences.)

FIG. 4 (*Lower*) Academy standard electrical characteristic for two-way reproducing systems in theaters.

ducing sufficient loudness in the auditorium. Coverage is also a variable factor, depending upon the proportions of the theater. The important "constants" of design are met by the use of two-way speaker systems with multicellular high-frequency horns and folded low-frequency horns in all systems, adhering to the general principles of the most acceptable systems used today.[1] The cross-over frequency of 400 cycles is standard for all systems. This and other "constants" are shown in Fig. 1 under the "Loud Speaker Equipment" column. The

various loud speaker combinations are also shown. The small system employs one A type high-frequency unit and one B type low-frequency unit; the medium system, two A and two B units; and the larger system, two C and four D units. The C and D units differ from the A and B mainly in power-carrying capacity.

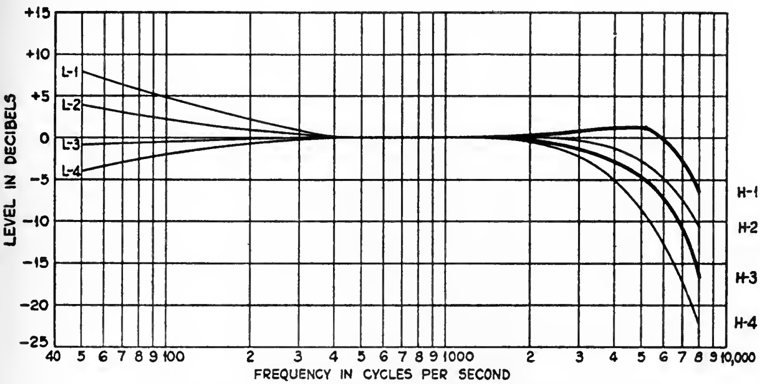


FIG. 5. Electrical characteristic of Simplex sound systems.

Fig. 2 is a schematic diagram of the system. The systems are engineered for two-projector installations which represent the majority of the cases, but a third projector can be added as shown by the broken lines. The power unit supplies exciter lamp power for two or three projectors. The control equipment consists of one volume control and change-over unit, supplied with each machine; a

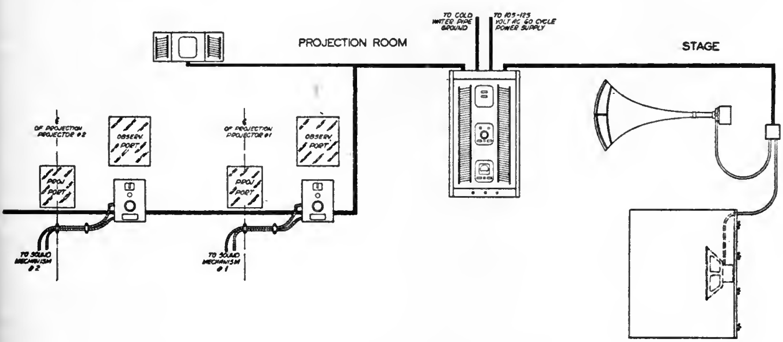
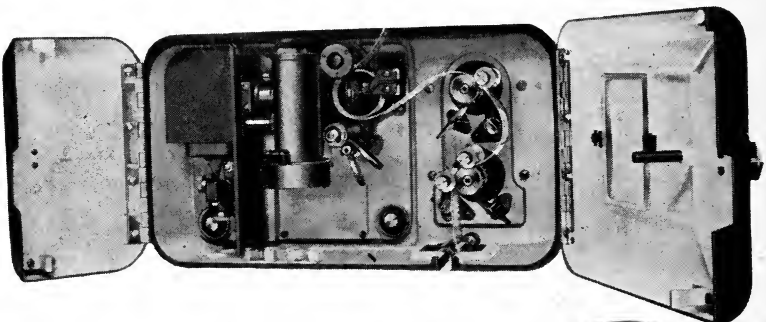


FIG. 6. Typical conduit layout.

third unit can be added for the third projector position. The outputs of the volume control amplifiers are connected to the main power amplifier—the single-unit amplifier is used in the small system. In the medium-size system another amplifier is added, as indicated by the broken lines; and in a still larger system the third and fourth amplifiers are added as shown. The two-way network and the

monitor speaker in the projection room are shown in solid lines, as they are used in all systems. The loud speakers for the small system consist of one low-frequency and one high-frequency unit; for the larger systems, to accommodate the increased power of additional amplifiers, greater power-handling capacity is provided by adding high- and low-frequency units, as shown in broken lines.

Academy Electrical Characteristic.—In addition to studying the field conditions and requirements with experts in the theater field, conferences were held with studio technicians and the Research Council of the Academy of Motion Picture Arts & Sciences. The work of the Council Committee on Theater Standardization is well known. Under the Chairmanship of J. K. Hilliard, the Committee has set up and adjusted various types of reproducing systems to sound reasonably alike, and from these experiments an average electrical characteristic for film reproducing systems has been established.[2] The primary objective of this work was to determine what considerations were required to insure uniformly good reproduction of the products of various Hollywood studios in the small as well as the large theaters. Unfortunately, the past, where reproduction by small theater equipment has been inferior to that of large theater equipment, the dramatic appeal of many productions has been impaired. This has quite seriously affected the general acceptance of some features as the small theaters (under 1000 seats) represent at least 84 per cent of the houses in the country. The medium-



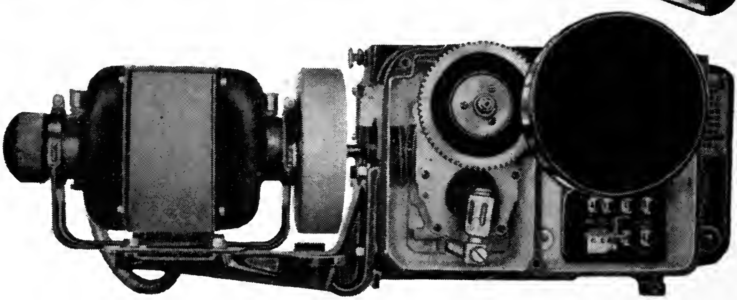


FIG. 7. (*Upper*) Sound mechanism, operating side.
FIG. 8. (*Lower*) Same, non-operating side.

size theaters (1000 to 2000 seats) represent about 13 per cent, and the larger theaters (over 2000 seats) about 3 per cent.[3] Our interest has been to develop good equipment for the small and medium-size theaters as well as for the large theaters. To assist further in a coördinated program, the Academy Committee has summarized general requirements for theater reproducing equipment. These have been carefully regarded throughout the design.

With respect to power output level, there have been established certain requirements regarding amplifier power for theaters of different size.[4] Fig. 3 shows a curve that has been agreed upon by various groups working with the Research Council. The abscissa shows seating capacity of the theater and the ordinate power output in decibles and in watts (0.006-watt reference level). The solid line is the preferred power rating; the lower line represents the minimum, and the upper line the desirable. In the new Simplex systems these requirements have been met in the small as well as in the medium and large systems, with at least 15 watts (34 db.) for the small, 30 watts (37 db.) for the medium, and 60 watts (40 db.) for the large systems. Larger systems are planned with the same consideration.

FIG. 9. Volume control amplifier.

Although the characteristic of the power amplifier may be made flat within ±1 db. up to 15,000 cycles, experience indicates that theater systems must be attenuated at high frequencies. Fig. 4 shows the standard electrical characteristic recommended by the Academy Committee.[2] The lower curve represents the average for metallic type diaphragms, and the dotted curve the average for nonmetallic diaphragms. Recognizing that these curves can not be used in all houses because of the variation of acoustic conditions, facilities have been provided in the design for obtaining other curves as shown in Fig. 5. (The two curves of Fig. 4 are shown on Fig. 5 as H_1 and H_3.) These characteristics are easily obtained by interconnection of elements provided as standard on a conveniently located terminal strip. Many other characteristics can be obtained by strapping the resistance and capacitance elements in other combinations.

One of the most important developments in recording has been the increase of volume range, which allows exhibitors to realize the full dynamic sound response and affords theater patrons complete realism in voice and music. A reduction in noise level as well as the increase of power is required to accomplish this. Each amplifier unit is tested, to be assured that the noise level is at least as low as −35 db. and that the power output is at least +34 db. (15 watts/0.006-watt reference level).

One of the critical limitations to volume range is the development of extraneous

noise in the sensitive amplifier circuits, often caused by dirty and imperfect contacts in the sound circuit and by the vibration of transformer laminations in circuits where iron-core transformers and chokes are employed. In the Simplex sound system the number of mechanical contacts in the sound circuit from the photoelectric cells to the loud speaker voice-coil has been reduced to a minimum. The main amplifier gain adjustment and the sound change-over have been placed in isolated circuits. The main amplifier gain adjustment is in the feedback circuit and the change-over is accomplished by bias control in the volume control amplifier. The individual volume controls at the machines are of special design, to reduce the introduction of noise from dirty sliding contacts. The reduction of the number of transformers and chokes materially lowers the noise level and greatly improves stability. The use of a coaxial cable to couple the photoelectric cell and the volume control amplifier further reduces noise. The reduction of noise and increase of power are the means through which wide volume range is obtained.

FIG. 10. Volume control amplifier (open).

DESIGN FEATURES AND DETAILS

Having reviewed the important requirements of present-day reproducing equipments with brief reference to the way these requirements have been met in this new sound system, the following is a more detailed description of the design features.

Fig. 6 is a schematic layout of a typical installation, showing the two projector positions with the volume control amplifiers and change-overs and the main amplifier cabinet and the monitor located in the projection room, with the loud speakers on the stage. Note the simplicity of installation, with conduits running from one position to the other, terminating directly in the apparatus cabinets. All circuits are easily pulled, the wires terminating in the cabinets without pulling through, thus simplifying installation.

Another consideration was the conservation of space in the projection room; with the development of larger pedestals and larger lamps there is not much space available in many projection rooms. Space taken by the amplifier equipment was reduced by making the cabinet serviceable from the front, so that the equipment does not have to stand out from the wall in order to provide space in the rear for access. All the conduits can be concealed because the construction

of the cabinets is such that they can be sunk partially into the wall without interfering with operation or ventilation. The wiring in the main cabinet is facilitated by the elimination of cable forms; the wires pass down behind the terminal strips which are mounted on studs forming a raceway. Jumpers between units are very easily installed. Specially designed terminal punchings insure good connections.

Fig. 7 shows the sound mechanism, operating side. Film motion past the scanning light-beam is controlled by the well known rotary stabilizer principle, insuring constant speed. The 4-ampere, 9-volt prefocused exciter lamp, of new design, has a short, sturdily supported filament minimizing vibration. The exciter lamp bracket is easily removable and is designed to permit vertical and lateral adjustments for exact positioning of the filament. The exciter lamp compartment is well ventilated, and careful shielding prevents any stray light from entering the photoelectric cell compartment.

A highly efficient oil-proof optical system projects a uniformly illuminated 0.084 × 0.0012-inch image upon the sound-track. A micrometer adjustment is

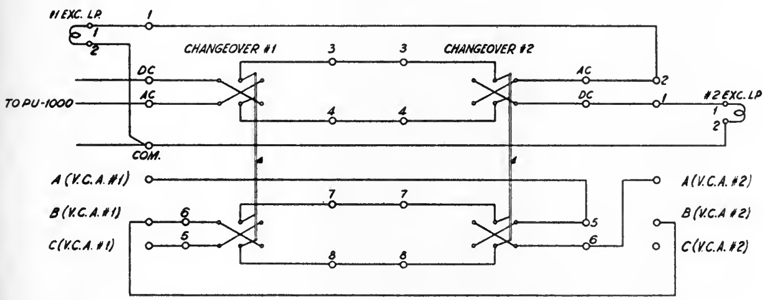


FIG. 11. Arrangement of change-over system.

provided for focusing. The reflector directs the light-rays to the photocell. It is a highly efficient ground and polished mirror. The guard ring around the mirror minimizes the possibility of putting finger marks on the lens while threading. The reflector is readily removable for cleaning and is easy to adjust.

The photoelectric cell is vertically mounted, eliminating vibration and microphonic noise. It is located away from the sprockets and out of the way of threading the machine. It is easily accessible for replacement; the front of the housing is hinged so that it can be opened easily, exposing the cell completely. Because of the cell position it is impossible for oil to reach and saturate the connecting wires and the socket, which are well protected in the cast photoelectric cell arm housing, and shielded from stray fields and static. The wires are cambric covered to eliminate trouble ordinarily caused by oil on wires.

Lateral film guide and pressure rollers are equipped with a trigger control. By merely pushing down on a lever the roller locks in position, and by a light touch on the lower lever it is tripped open. There are no knobs or handles to pull out or turn. In open position the roller is well out of the way. As a safety feature, it has been arranged that the film compartment door can not be closed with the roller in open position.

The "sound bracket" is a unit assembly consisting of the exciter lamp, optical system, rotary stabilizer, scanning drum, reflector, and photoelectric cell, and is rigidly mounted on a heavy bracket attached to the main frame with a three-screw, shock-absorbing mounting. The bushings are impervious to oil.

The drive motor is a cradle-suspended, oversize, $^1/_4$-hp., split-phase induction motor with ball-bearing mounted rotor, and thrust bearings on both ends, insuring

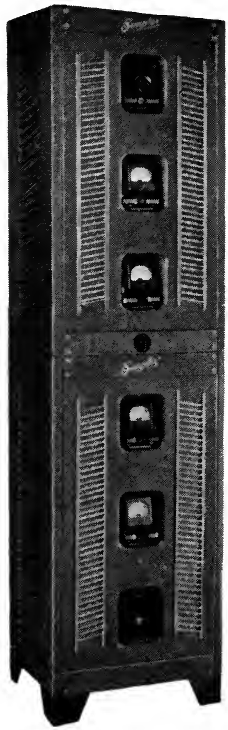


FIG. 12. (*Left*) Main cabinet.
FIG. 13. (*Right*) Showing method of mounting two-cabinet assembly.

constant speed with a variation of less than 0.5 per cent with voltages from 102 to 125 volts. A flywheel insures correct starting speed meeting the SMPE. Projection Practice Committee's recommendations of two to three seconds. The manually operated motor brake quickly stops the machine in case of film breakage. The knob on the end of the motor facilitates threading, and a flexible coupling between the motor and the gear box filters out mechanical vibrations.

The film-drive sprockets consist of a sound sprocket and a hold-back sprocket, to prevent the reflection of take-up jerks from disturbing the film at the scanning point. All shafts of the drive mechanism rotate on dust-proof ball bearings.

Special shaft construction insures alignment of the sprockets, avoiding variation caused by the accumulation of allowances on the individual parts.

The drive mechanism is one assembly. It consists of the gear-box, sprockets, shafts, pad rollers, and stripper plates, all of which are easily removable as a single unit by removing four screws. This construction affords the facility of building a gear-box as a precision unit and then mounting it into the main frame casting in a manner similar to that normally employed for intermittent movements in projectors.

Fig. 8 shows the oil gauge which gives visual indication of the oil level in the reservoir. Proper lubrication of the sound mechanism is insured when the oil level is maintained.

The sound-head design insures accurate alignment of the projector drive gears and easy installation or removal of the projector mechanism. Micrometer adjustment is provided to obtain proper and accurate gear mesh. A bar is fastened to the bottom of the projector mechanism. This bar fits into a slot in the top of the sound mechanism. It is under-flush with respect to the sound mechanism slot, so that the finished pads of the projector mechanism are in contact over their entire area with the finished pads on the sound mechanism. The projector mechanism is locked to the sound mechanism by two machine screws which pass through elongated holes in the bar. No serious strain can be caused by pulling down on these screws because the bar is very narrow and the base of the projector mechanism casting is in contact with the sound mechanism over a large area. The micrometer adjustment is provided by a screw in the front. When the projector mechanism with the bar is set on the sound mechanism, the screw is run up so as to prevent clashing of the gears and breaking of the teeth. After the mechanism is in position the screw can be backed out and the mechanism moved so that the gears come into proper alignment. The 40-thread pitch of the screw permits easy adjustment for accurate gear mesh, insuring long life and reduced operating noise.

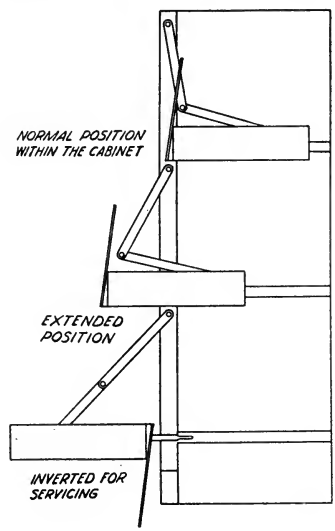


FIG. 14. Main cabinet chassis positions.

The sound head is designed for the future, as it may be easily and economically converted for the reproduction of push-pull or stereophonic recordings whenever these forms of recording become popular.

Fig. 9 is in view of the volume control amplifier unit. The cabinet is neat and compact; permits mounting on the front wall of the projector room. Fig. 10 shows the inside of the cabinet. The amplifier consists of a two-stage resistance-coupled voltage amplifier employing RCA *6J7* tubes; it has 46-db. gain. Its normal operating position is 26 db., which puts the volume control mid-range.

Metal type *6J7* tubes were selected for their shielding, uniformity, and freedom from microphonic tendencies. The coaxial cable coupling the photoelectric cell to the volume control amplifier enters the cabinet in such a manner that the connecting lead to the amplifier is very short. The cable is shielded and covered with a cambric tubing to prevent entrance of oil; over the tubing is an armored sheath to protect it mechanically. The volume control for the system is a specially designed detented step-by-step potentiometer having nineteen 2-db. steps.

Fig. 11 shows schematically the circuit of the electronic sound change-over, which comprises a three-way switching arrangement, one at each projector station, to control the bias of the second stage of the volume control amplifier. This method of change-over control eliminates relays and mechanically interlocked switches; it is instantaneous and noiseless, since it avoids the necessity of breaking the signal circuit. Switching may be done at either projector. The exciter-lamp circuit is transferred simultaneously. The photo-electric cell balancers

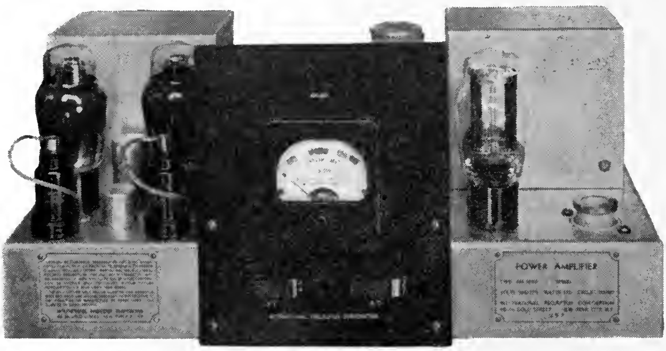


FIG. 15. Power amplifier.

equalize the signal input to the power amplifier at predetermined levels to obtain uniform output from each machine. A handy control with a slider and a clamp is provided. The pilot light in the volume control amplifier cabinet indicates which machine is in use.

The cabinet is designed to accommodate two amplifier units, which can be connected to provide an emergency volume control stage or dual channel operation. A switch on the terminal strip of each unit makes connections simple and practicable. Extra units can be added at any time. The two amplifiers are identical and mount so that their volume controls are operated simultaneously by the one control knob.

Fig. 12 shows the main cabinet, which is a three-section unit designed for floor or wall mounting. In a single-cabinet installation it is usually mounted on the wall. Where two cabinets are used, one is placed above the other mounted on a set of feet as shown in Fig. 13. Louvers on the front and sides provide adequate ventilation. The front panel clips into place and is quickly and easily removed without tools. Each unit in the cabinet may be partly withdrawn and rotated

180 degrees for examination or servicing while in operation, as shown in Fig. 14 which schematically shows the arrangement of the cabinet. Three chassis positions are shown: the normal position within the cabinet; the position when withdrawn before rotating, and the inverted position, after being rotated 180 degrees. The chassis can not be inverted until it is drawn out; this provides a fool-proof feature and prevents interference between chassis. This arrangement permits compact construction.

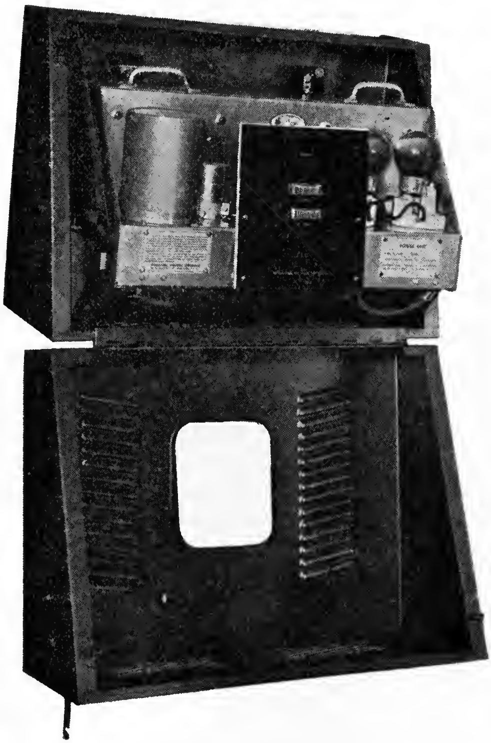


FIG. 16. Power unit in single-section cabinet.

Fig. 15 shows the power amplifier. It employs resistance coupling interstage. The elimination of iron-core transformers and reactors reduces noise. The only iron-core component in the signal circuit is a matching transformer to couple power tubes to the speaker network. The power output is 15 watts at frequencies as low as 50 cycles, with less than one per cent total harmonic distortion. The a-c. circuit is separately fused with the fusetron conveniently located.

The entire system is designed to employ a minimum number of standard tubes of metal or glass types universally obtainable. Although metal *6J7* tubes are used for the reason given, glass *6L6* type tubes are preferred for uniformity and dependability. The tubes in the power amplifier are *6J7* in the driver stage, *6J7*

in the phase inversion stage, two *6L6G* tubes in the push-pull power output stage, and a *5Z3* full-wave rectifier. A meter is mounted on the power amplifier panel for testing the condition of the tubes. The scale on the meter is blocked off in red and green sectors. Green means the tube is all right, and red indicates that replacement of the tube whose number appears in the red block is desirable.

An auxiliary volume control in the feed-back circuit of the amplifier affords variable control over a 12-db. range and permits extension of this potentiometer circuit for remote volume control. The arrangement known as the "warping circuit," for adjustment (by soldered connections) of the electrical characteristics, are connected into the feed-back circuit. Adjustments are provided that permit four curves in the low-frequency range and four in the high-frequency range.

Parallel operation of the amplifiers, as previous described, affords a very economical means of providing emergency facilities in any system where more than one power amplifier unit is used, as a simple switching arrangement is incorporated that permits selection of various units individually or as parallel groups. The circuits are arranged so as to isolate the defective units and permit repairs or replacements to be made while the system is in operation. In the small system employing one amplifier, a second unit, together with a selective switching arrangement, can be easily added. Means for mounting the switches are provided in the lower stationary panel of the cabinet.

The exciter lamp power unit (Fig. 16) employs two 2-ampere Tungar bulbs to furnish direct current held within close limits, variations in line voltage being compensated for by a ballast lamp regulating circuit. The lamp of the operating machine is connected to the rectified output of the power unit while the lamp of the "OFF" machine is connected to a transformer at one-fourth the normal a-c. operating voltage. On change-over the circuits are automaticaly switched. Keeping the lamp hot insures uniform volume on change-over without burning the lamp at full rating at all times. Using alternating current on the "OFF" machine provides a more economical arrangement for several reasons: first, the lamp life is preserved; second, the rectifier construction and power consumption are less expensive. Furthermore, by the same facilities and by simple operation of one switch, the lamps may be operated on alternating current at normal rating, thus providing an emergency operating condition in the event of failure of the rectifier circuit. The a-c. circuit employs a separately fused transformer and circuit that permit testing and inspecting the rectifier while the system is in operation. A-c. operation of the exciter lamp also provides a very convenient test circuit for balancing the photoelectric cell output when adjusting the sound mechanism for reproduction of push-pull tracks; that is, to determine the cancellation effect.

The loud speaker network shown in Fig. 17 couples the amplifier output to the two-way loud speaker system with a 400-cycle cross-over. Special design features, careful selection of capacitors, resistors, and other parts afford stability of operation under all conditions. The control panel incorporates two switches, marked *HF* and *LF*, which permit high- or low-frequency speakers to be operated as separate groups. This feature is of special value in testing and for continuing operation in the event of failure of any speaker unit. Where more than one high- or low-frequency speaker is used, additional selective switching arrangements may be added for further flexibility. Holes are already provided in the panel for

easy installation and a terminal strip is provided to facilitate connections. The panel also includes the monitor loud speaker volume control and a jack for headset monitoring. The volume control of the monitor loud speaker can be adjusted from the amplifier location, which is usually mounted convenient to the machines. With the *HF* and *LF* switches set to disconnect all loud speakers, a terminating resistance is automatically connected across the amplifier output, permitting a volume indicator or output meter to be conveniently plugged into the monitoring jack for checking the amplifier frequency characteristics. When the *HF* switch only is operated, so that the high-frequency loud speaker leg is disconnected, the network is automatically by-passed, and the low-frequency loud speaker operates directly from the amplifier output as a full-range speaker, thus permitting emergency operation. When only the *LF* switch is operated, so that the low-frequency loud speaker leg is disconnected, a resistance is automatically substituted for this speaker unit thus permitting the high-frequency speaker to continue operation in the normal manner.

FIG. 17. Loud speaker network.

Fig. 18 shows the loud speaker system for the small theater. The high-frequency loud speaker assembly consists of a multicellular exponential horn of new design employing a spherical mouth opening and eight-cell construction for high quality and wide-angle distribution, insuring uniform balance of the frequency spectrum. The high-frequency unit is of the permanent-magnet dynamic type. It incorporates a high safety factor in relation to power limits required in normal operation.

The low-frequency speaker is a folded exponential horn of solid and sturdy wood construction. New and unique in design, it avoids undesirable reflection conditions. The enclosed back minimizes back-stage reflections and draping. The low-frequency unit is of the permanent-magnet dynamic type. It possesses high power-handling capacity and efficiency over the frequency range for which it is designed. This type of equipment is used in the small and medium systems.

The use of permanent-magnet loud speaker units brings to the theater reproducing field one of the lastest most important improvements in loud speaker equipment. Improved alloys make it possible to produce practicable, dependable, and

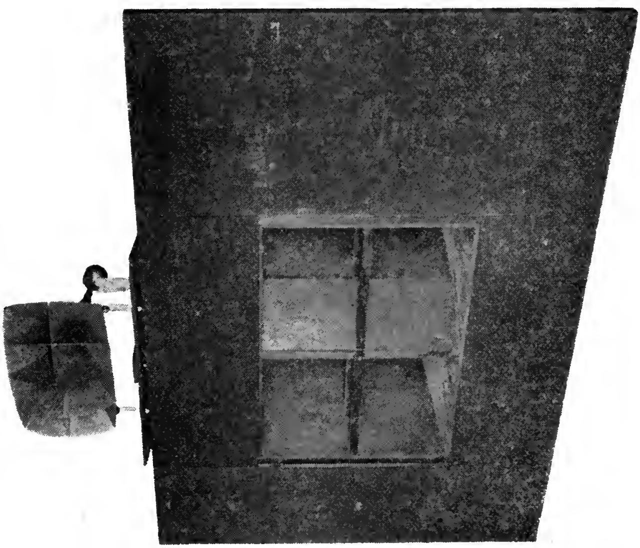


FIG. 18. (*Left*) Stage loud speaker equipment; small system.
FIG. 19. (*Right*) Same; large system.

economical permanent magnets where the field structures required are not too large. Permanent magnets have been used in light-valves, microphones, and precision instruments, where uniformity is paramount. Permanent-magnet field structures on loud speaker units eliminate the loud speaker rectifier and the electromagnet. Both these elements are susceptible to operating variations that affect the magnetic field strength and the speaker performance: for example, the output of the rectifier may vary as a function of the input voltage and the con-

FIG. 20. (*Upper*) Monitor loud speaker.
FIG. 21. (*Lower*) Monitor amplifier.

dition of the tubes; the voltage at the loud speaker fields is dependent upon the voltage drop in the stage line; the magnetic field strength may be further varied by the operating temperatue of the field coil. Variation of these factors can not be detected easily, and the cumulative effect in degrading the system performance may be appreciable. Permanent-magnet fields are not subject to such variations. The field strength is constant and the performance uniform for indefinite periods. "Ageing" is negligible. Installation expenses of rectifiers and stage lines for field supply are eliminated as well as maintenance expense.

Fig. 19 shows the loud speaker equipment proposed for use with the large system.

The monitor loud speaker shown in Fig. 20 consists of a permanent-magnet 8-inch cone unit with a two-way baffle arrangement. The high frequencies are projected through the center grille directly from the front of the loud speaker cone and the low frequencies are radiated through the louvers on both sides of the grille, being reinforced by the folded baffle path between the rear of the cone and the louvers. The design extends the frequency response over that generally found in monitor speakers. It offers a truer and more pleasant degree of reproduction. It permits easy cueing of dialog and also gives low-frequency response, enabling the projectionist to detect extraneous noises such as sprocket-hole and frame line modulation.

The monitor amplifier shown in Fig. 21 can be used with any system to provide more power in the projection room for the monitor level. It employs a type *6N7* metal tube as a push-pull stage. Installation is simple, since it plugs into a socket provided on the loud speaker network chassis. A switch mounted on the speaker network chassis permits by-passing the monitor amplifier, in which case the monitor speaker functions directly from the power amplifier with the same volume control potentiometer.

OPERATING ADVANTAGES

There is nothing more serious than a black screen in the theater. A unique degree of dependability is incorporated in this new Simplex sound system, which permits uninterrupted operation under a wide variety of conditions, precluding the possibility of any protracted failure of sound. To summarize:

(*a*) Simplex main amplifiers are all designed to permit, by the simple operation of a switch, parallel operation with provisions for emergency operation and isolation of the faulty unit or units.

(*b*) Volume control amplifier cabinets are designed to accommodate two amplifiers and suitable switches. In the event that one fails, operation may be instantly continued on the other.

(*c*) The power unit furnishes direct current to the exciter lamps for highest-quality reproduction and includes a switch permitting instantaneous operation of the exciter lamps from alternating current through a separate transformer.

(*d*) The use of modern permanent-magnet dynamic speakers eliminates the loud speaker field supply rectifier and insures uniform uninterrupted performance.

(*e*) Provision is made to operate either the high-frequency or low-frequency loud speaker units alone in case of emergency, by the simple operation of a switch.

Designed for the Future.—While it is difficult to foresee all the possible developments that may be made in the future in the sound motion picture field, provisions have been made in the design of the Simplex sound system for those developments that to date have shown outstanding merit and the application of which is being encouraged by certain Hollywood producers to add greater realism to the sound: namely, post-equalization, push-pull and stereophonic reproduction, and increased power, for which Simplex sound systems incorporate the necessary design flexibility and space for easy and economical adaptation.

The sound mechanism can reproduce push-pull and stereophonic recordings by the simple addition of a few items: for push-pull the reflector and the photo-

electric cell can be replaced and a coupling mesh added; for stereophonic the reflector and photoelectric cell can be replaced and a second coaxial cable added. The volume control equipment can be modified for stereophonic reproduction by the addition of a second amplifier unit in the present cabinet. Dual channel operation of the amplifier system can be accomplished easily by splitting up the units of any system or by adding units of uniform physical size. Extra amplifier units for increased power can also be installed easily because of the unit construction and cabinet design. The post-equalizer can be added to the volume control cabinet assembly as it is designed to replace the name plate in the lower part of the cabinet.

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DISCUSSION

MR. DEVRY: What instrument is used to determine the 0.15-per cent flutter?

MR. FRIEDL: The flutter was measured on an ERPI flutter bridge, an instrument designed and used for studio work as well as theater testing. Several papers describing the equipment were published in the Journal by R. R. Scoville.[5]

MR. CRABTREE: I understand that the energy emanating from an orchestra may be as high as 150 watts. Your power maximum is 15 watts. Is that enough output to similate a full orchestra?

MR. MAXFIELD: There are some occasional instantaneous peak values whose duration is less than one-eighth of a second each. These contribute little to the loudness. The average maximum is about 8 db. below these short duration peaks. Instantaneous peaks are all knocked out in the recording mechanism anyway, and therefore do not enter into the problem.

MR. CRABTREE: Can you connect together two or three more amplifiers and increase the output?

MR. FRIEDL: Yes, although we do not know how far we can go in that direction. Our present systems are meeting the recommended power requirements; and as a matter of fact the capacities are much higher than those of similar systems used in many theaters today, the small one being 15 watts.

MR. FISHER: The data given in Fletcher's paper are in acoustic watts, and the data here are in electric watts; 15 watts here probably represents 3 or 4 acoustic watts.

MR. FRAYNE: Is there a transformer in the output circuit of the photoelectric cell?

MR. FRIEDL: It is coupled directly by the coaxial cable.

MR. FRAYNE: What is the length of the cable?

MR. FRIEDL: Between five and six feet, because of the distance of the mechanism from the wall.

MR. FRAYNE: You have no trouble on that basis?

MR. FRIEDL: No.

MR. FRAYNE: Do you have to equalize for it?

MR. FRIEDL: No. The loss is very low and corresponds to the attenuation rate of the recommended electrical characteristic.

MR. CRABTREE: What is the advantage of the permanent magnets in the speakers, and is there any loss of magnetism with time?

MR. FRIEDL: They avoid rectifier equipment, which is subject to failure, and also the field coil, which is likely to break down and which varies with temperature. The life of the magnets is indefinite so far as measurements indicate.

MR. ROBERTS: Since the reproducing drum and the sound sprocket are not mounted on the same casting, how critical is the axial alignment between them? I am thinking of possible film weave due to misalignment of drum and sprocket.

MR. FRIEDL: We control that by a construction that does not depend upon a resilient mounting for alignment. There is definite alignment even though the sound bracket, which is a separate assembly, is insulated from the main frame. It is not set out on a spring or on a unit that might sag.

MR. FRAYNE: Are the horns in this installation capable of transmitting the frequency range beyond that shown in the characteristic curves for the high end? The curves show a drop, say, of about 20 db. at 8000 cycles.

MR. FRIEDL: On this system here we are using the H_2 characteristic which falls between the Academy "metallic" curve and the Academy "non-metallic" curve.

MR. FRAYNE: The curves that the Academy published were formulated on the basis of tests using the horn system then available. It is probable that some new tests will be necessary to establish new curves with these particular horns?

MR. FRIEDL: Possibly; recognizing that possibility, we do not insist upon using the metallic characteristic, H_3, but provide for the additional characteristic H_2. Incidentally, the tests made in Hollywood were made on only very large, expensive loud speaker equipment far too expensive to be offered commercially to a small theater.

MR. DEVRY: Is it not expensive to use two 15-watt amplifiers to get a 30-watt output, rather than to use one made for 30-watt in the first place? I imagine

that the expense would be probably 75 per cent over what it would be in a 30-watt amplifier.

MR. FRIEDL: That would probably be so if we were building only 30-watt amplifiers; but since we must build a 15-watt amplifier we can standardize on it, thereby transferring the economy to the customer and, in addition, giving him an emergency operating provision, which is very important. When one 30-watt amplifier fails, the house is dead; two 15-watt channels operating in parallel permit carrying the show on either channel, switching facilities having been provided for such contingency.

MR. DAY: How long does it take the flywheel to attain full speed after the machine starts?

MR. FRIEDL: Approximately six seconds.

MR. DAY: Does it slip over the drum, or does the oil clutch provide the slip?

MR. FRIEDL: I believe both things happen. The oil clutch is the well-known rotary stabilizer. Incidentally, one potential danger is oil leakage, which would affect the damping of the unit. We have dead-ended the drum so that there is no possibility of leakage. We have eliminated screws and gaskets on the cover by spinning the shell enclosed over the cover, so that it will stand at least 85 pounds pressure with no sign of leakage.

VARIABLE MATTE CONTROL (SQUEEZE TRACK) FOR VARIABLE-DENSITY RECORDING*

G. R. CRANE**

Since the advent of sound motion pictures, the need has been felt for an increased sound volume range in the theater to provide for the greatest possible dramatic and musical expression. For special occasions the gain of the reproducing system may be altered continually or intermittently by cues, but for the average theater this practice is expensive and inconvenient, and it is generally conceded that the recording medium by itself should provide the total possible volume range. With film as the recording medium the upper limit is generally represented by the overload point of the photographic record. The lower limit is usually that of the film background noise, which at the present time is still somewhat above the audience noise during moments of dramatic interest.

A number of methods of increasing the total volume range on the film have been suggested and some have been used with a fair measure of success; but this paper describes one method in which the width of variable-density sound-track is reduced during quiet, or relatively low-level, portions. This system, commonly known as "squeeze" or matted track, appears to have been first used on a commercial scale by MGM Studio. It was originally used as a means of adjusting

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* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 18, 1938.

** Electrical Research Products, Inc., Hollywood, Calif.

the volume of the release print, either in the printing or in the re-recording process, as described in a paper by W. C. Miller, 1930.[1]

The upper limit of signal volume is essentially fixed by the present film emulsions, but an extension of the total range may be obtained by a reduction of the background noises. Therefore, in any system of noise reduction, the fundamental purpose is that of keeping the ratio of significant signal to the background noise as high as possible. During the louder passages of the reproduced sound-track, the background noise is masked by the signal and becomes objectionable only during the low-level or silent passages. Therefore, the noise-reduction system acts upon the sound-track in such a manner as to reduce the background noise and permit recording lower-volume signals without loss of intelligibility.

The principal causes of background noise are generally film-grain noise and the hiss of the photoelectric cell, excluding, of course, the miscellaneous noises caused by scratches and dirt on the film. It has been found that the background noise varies with the amount of light falling upon the photoelectric cell. To reduce the noise, the transmission of the sound-track may be automatically reduced during quiet passages as is done in the variable-density noise-reduction system; or the track modulation may be followed by a masking envelope, as is employed by the variable-area noise-reduction systems. With the variable-density system, the width of the sound-track may also be reduced, which, of course, further reduces the amount of light falling upon the photoelectric cell.

The relationship between the width of the sound-track and the resulting signal and background noise is the basis for the application of squeeze track to variable-density recording, and it might be in order to review the fundamentals of this relationship. One manner of approach is to consider the sound-track as composed of a summation of a large number of small tracks, side by side. These tracks are modulated and scanned by a single slit; and if we consider the voltage generated by the photoelectric cell, each small track will contribute a voltage that is in phase with every other voltage component, and the total voltage is the sum of the individual voltages. Expressed as an equation, the total voltage, $\Sigma E = e_1 + e_2 + e_3 + \ldots . e_n$, and it follows that for a uniformly modulated track, uniformly scanned, the signal output will vary directly with the width of the track.

In like manner we may consider the film background noise due primarily to film emulsion graininess. The individual noise voltages generated by each track are altogether random and differ in magnitude, phase, and frequency. As in the case of other physical phenomena involving the summation of random distribution, the total voltage, $E_{noise} = \sqrt{e_1^2 + e_2^2 + e_3^2 + \ldots e_n^2}$. Applying these relationships to the simple case of two identical tracks, for example, the signal voltage becomes $2e$, whereas the noise voltage becomes $\sqrt{e_1^2 + e_2^2}$, which is $\sqrt{2e}$. From this it may be seen that signal output varies directly with track width, whereas noise varies as the square-root of the width. Consequently, doubling the sound-track increases the signal 6 db., but the noise is increased by only 3 db., and the signal-to-noise ratio is thereby increased by 3 db. for the ideal case. These relationships have been discussed in greater detail in a recent paper by W. J. Albersheim,[2] and have been demonstrated experimentally as described in an unpublished paper by W. R. Goehner and N. R. Stryker of the Bell Telephone Laboratories.

As previously mentioned, squeeze track is applied only during relatively low-level passages, during which, for a given reproduced volume, the modulation is relatively higher and the sound-track narrower than for a standard sound-track, resulting in less background noise. In re-recording practice, squeeze track may be employed in either of two ways. In the first method it may be used by the mixer as a volume-reduction device instead of the reduction of modulation by the volume control. If, for example, it is required to re-record a given passage at, say, 10 db. down from normal, he may either introduce 10 db. of attenuation in the recording circuit, or he may squeeze the track by 10 db. Either operation will give the same signal output from the film, but in the latter case he will have reduced the background noise by 5 db. and increased the signal-to-noise ratio by the same amount. The second method of use is that of obtaining additional noise reduction. On low-level passages the mixer may squeeze the track, say, 10 db.,

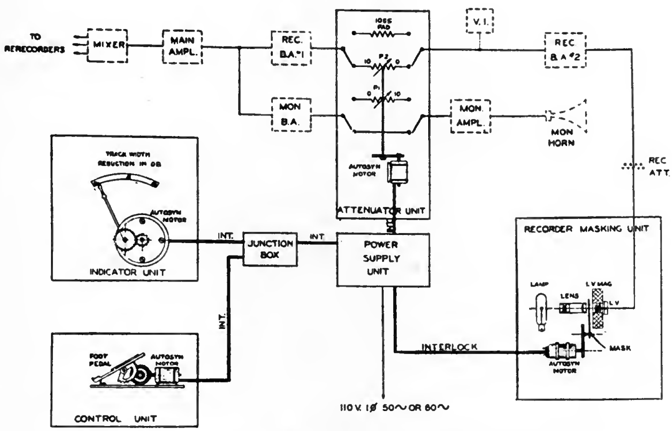

FIG. 1. Schematic diagram of equipment.

and simultaneously increase the modulation by 10 db., thereby reducing the noise 5 db. but not changing the signal output from the sound-track. When using the equipment in this manner, suitable precautions must be taken, of course, to prevent overload of the light-valve. Obviously, the two methods are functionally identical, and differ only from the standpoint of operation and circuit arrangement. It should be pointed out also that to attain the maximum benefit from squeezed track, it is essential that the material being recorded be fully modulated with the greatest possible signal-to-noise ratio.

The limit to which the track width may be reduced is not fixed definitely but experience has indicated that it is somewhere between 10 and 15 db. At 12 db., for example, the track has been reduced from 76 to 19 mils, or if a *W* type mask is used the two tracks are 8.5 mils each. For widths less than 8.5 mils, noise introduced by miscellaneous dirt particles or scratches on the track tends to become serious, since for a given size of particle the percentage modulation increases as

the track width decreases. At the present time, 10 to 12 db. appears to be the practical limit for commercial use.

Sound-track matting equipment has therefore been developed to provide the facilities for 10 db. of sound-track matting to be used with the existing studio channel equipment and the standard types of variable-density recording machines. It is a system composed of four principal units which are coupled and driven by Selsyn type interlock motors to provide a means of altering the width of the sound-track by remote control and simultaneously changing the amount of attenuation in the recording or monitoring circuit. Fig. 1 is a schematic diagram of the system.

The four principal units are the recorder masking unit, the foot pedal control unit, the indicating meter unit, and the attenuator unit. In addition to these, a junction box is provided for termination for the cables to the control unit and the meter unit; and a power-supply unit is required because of the differences in electrical characteristics of the several motors involved.

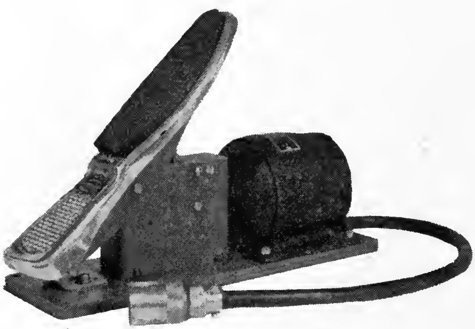

FIG. 2. Foot-pedal control unit.

Foot-Pedal Control Unit.—This unit consists of a foot-pedal mounted upon a small gear-box which drives a type *I* Autosyn motor as shown in Fig. 2. The angle of rotation of the foot-pedal is about 34 degrees with a gear-box adjusted to give the driving motor a total rotation of exactly 720 degrees. These values were chosen somewhat arbitrarily with a view in mind to provide a large, but convenient angle for operation of the pedal by the foot. One fixed and one adjustable stop are provided as well as an adjustable friction clutch, so that the operator may rest or remove his foot from the pedal without altering the setting. The unit is mounted upon a steel base-plate covered with sheet rubber, and the weight is sufficient to prevent it from sliding on the floor when operated by the foot. The motor leads are covered with a rubber sheath and terminated by a Cannon plug, to allow it to be disconnected quickly.

Indicating Meter Unit.—The indicating meter unit is an assembly built within a standard type of meter case and driven by a type *769* Autosyn motor as shown by Fig. 3. The meter assembly includes a gear reduction between the motor and the pointer of 6:1 so that the pointer travels through 120 degrees, corresponding to the motor rotation of 720 degrees. The dial is calibrated in 1-db.

steps from 0 to 10 db. It is mounted in a sheet metal case, as shown in Fig. 3, with the meter dial indirectly illuminated. A shielded cable carries the motor circuits and also terminates in a Cannon jack. The meter unit can be supplied without the case, although the case permits placing the meter at any point convenient for the operator.

Attenuator Unit.—This unit consists of a type *I* Autosyn motor driving a special potentiometer through the proper gear reduction, and is mounted upon a standard relay rack panel as shown by Fig. 4. The potentiometer travels through its complete range corresponding to the 720-degree rotation of the motor. It has two electrically separate potentiometers, each having 10 db. of attenuation in steps of $^1/_2$ db. They are mechanically one unit driven by a common shaft, one of which increases attenuation as the other decreases. Two relays switch these potentiometers by the operation of a key located at the mixer position or elsewhere. In the construction of this potentiometer, care has been taken to insure good contact between the wiper and the studs with a minimum of friction, the detent assembly being omitted. A steel cover acting as a dust and magnetic shield is readily removed. One terminal strip is used for motor circuits and another for the speech circuits.

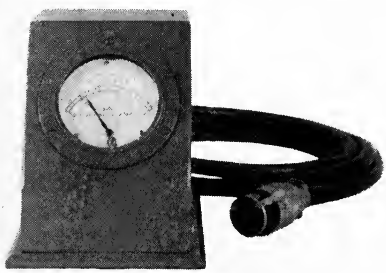

FIG. 3. Indicating meter unit.

Recorder Masking Unit.—Fig. 5 shows the recorder masking unit mounted upon the optical bench of the *100-AA* recorder. It is essentially a conventional light-valve magnet and a new optical system, both of which are mounted in special support casting.

The optical system consists of two units. The larger unit is a tube having a combination cylindrical and aspheric condenser lens in one end and a so-called "collector" lens at the other. The small unit containing an achromatic doublet, called the "relay" lens, is mounted inside the magnet bore near the front of the magnet. With this optical system, a diffuse image of the lamp filament may be brought to a focus by the condenser lens at a plane just beyond the collector lens and just behind the light-valve magnet. A movable mask is placed at this plane, and the mask and filament image are then focused upon the plane of the light-valve ribbons by the relay lens. It is apparent, therefore, that by changing the dimensions of the mask, the length of the illuminated area of light-valve slit may be altered, thereby altering the width of the sound-track proportionately. The function of the collector lens is to avoid loss of light by focusing the aperture of the condenser lens upon the aperture of the relay lens.

The mask opening has been designed in the shape of a circular wedge sector rotating through an angle of 36 degrees, being driven by an Autosyn type *781* motor through a gear reduction of 20:1. The mask has been designed for a track reduction of 10 db. starting from a basic width of 76 mils. This track width was selected so that the sound-track will always be its own masking agent, and have adequate clearance within the normal 80- to 84-mil mask provided by the reproducing optical system. This condition is necessary if the proper ratio of track

reduction is to be realized on all the types of reproducing equipment. In addition to this requirement, the studio receiving the first set of equipment requested a *W* type mask which inserts a septum in the center of the track as part of the reduction in width. Fig. 6 shows the masking unit with the guard removed, allowing the mask to be rotated out into full view. The mask as shown was cut for a reduction of 10 db. in steps of 1 db., as described later.

This unit may be mounted on the standard recorder without extensive modifications of the recorder. The lamp in each case is mounted by means of the lamp bracket supplied with the recorder. Equipment has not at this time been designed for use with the smaller portable type recorders.

Power-Supply Unit.—This unit contains the step-down transformer supplying power to the small motors, and three small transformers are connected 3-ϕ *Y* to couple the rotor circuits of the small and large motors. Terminal strips are provided to serve as a termination for the motor circuits to the various units. This equipment, together with a switch and signal light, is mounted in a relay rack panel and could be combined with either the attenuator unit or the junction box,

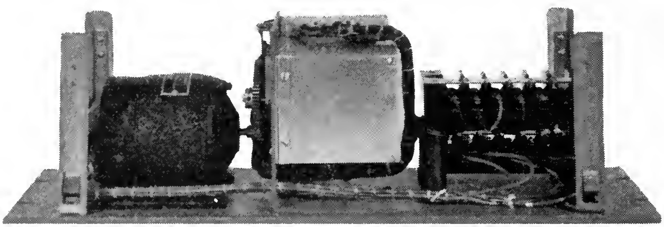

FIG. 4. Attenuator unit.

if desired, but has been kept as a separate unit to provide flexibility in equipment arrangement.

Junction Box.—A junction box terminates the permanent wiring to the mixer's position and provides plug connections for the foot-pedal and the indicating meter units. It also mounts a key to operate the attenuator unit relays controlling the potentiometer circuits. This unit could readily be eliminated, but is required in case several stages are wired for this equipment, since foot-pedal and meter units may then be moved quickly from one stage to another.

Motor Drive System.—The motors used in this equipment are of the single-phase, Selsyn type, which are marketed under the trade name "Autosyn." The foot-pedal control unit and the attenuator unit employ two of the larger size motors known as the type *I*, which require 110 volts a-c. on the stators. The recorder masking unit uses a small type known as the *851*, and the meter unit uses the type *769*. These two small motors are identical except for the length of the stator and rotor, the *851* being approximately $^1/_2$ inch longer and having nearly twice the torque of the *769*. These motors require 32 volts a-c. which is supplied by a step-down transformer. Each of these motors has a 3-phase winding with induced voltages of 54 volts in the large motors and 24 volts in the small motors.

In order that these circuits may be properly coupled, it is necessary to supply a 3-phase Y-connected autotransformer of appropriate voltage ratio.

These motors have a lag not exceeding $1^1/_2$ degrees at zero torque and an additional displacement from the true interlock position which is small, but proportional to the torque imposed. In order to minimize this error, the system has been designed so that the motors turn through a considerably greater angle than the operating elements, which was chosen to be two complete revolutions, or exactly 720 degrees. In each of the units described, appropriate gear ratios have been supplied to operate the moving elements as required. Each motor has one interlock position per revolution and it is therefore possible to energize the system and have one or more motors out of proper relationship by either 360 or 720 degrees. By the use of definite and rugged end-stops on each unit, one complete cycle or operation of the foot-pedal automatically aligns all motors in the system. During

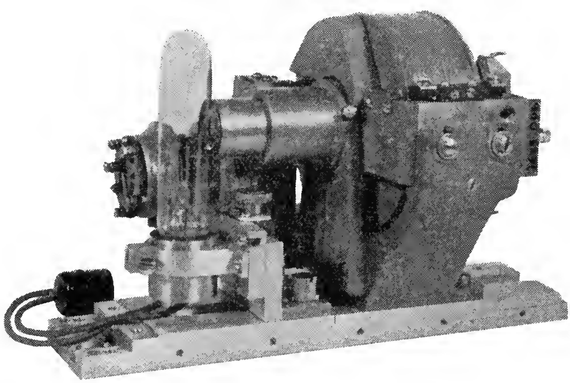

FIG. 5. Recorder masking unit.

this operation any motor that is out of alignment will come against its limiting stop and will pull through one interlock position to the next, and thus all motors are brought into proper relationship. The normal operation of the system is limited only by the adjustable stop on the foot-pedal, the end-stops on all the other units having slight clearance from the normal end-positions of their mechanisms. This is necessary to prevent possible chattering of the stop mechanisms when the system is set for either end-position.

Each motor-driven unit is provided with an adjustment for accurately aligning its movement with that of the foot-pedal. The foot-pedal unit is set up with reference to a standard, so that any unit of a system may be interchanged without disturbing its adjustment. Additional motors could be connected to the system for other purposes, the number depending upon the capacity of the foot-pedal driving motor, and the method of operation.

Mask Design.—The mask is designed empirically, taking into account the non-uniformities in commercial recording and reproducing systems. As previously mentioned, the mask openings are designed to give the required reduction starting from a full track width of 76 mils with ten 1-db. steps including one step in the

septum. To conform to studio practice we have provided a mask of the *W* type which inserts a septum as part of the reduction in width. This tends to make the film reduction in output more nearly conform to the expected values based on sound-track dimensions, since the remaining portions of the matted track are neither center nor edge portions, but intermediate areas which tend to be about average with respect to modulation, track density, *etc.* A second advantage in the *W* mask lies in the fact that it is also well suited for use with push-pull sound-track. Because of the septum line of the push-pull track, the first step will be less than 1 db. and the successive steps will be in 1-db. increments; and this may be compensated for by an adjustment in the attenuator. If the system is to be used interchangeably for standard and push-pull recording, the indicating meter

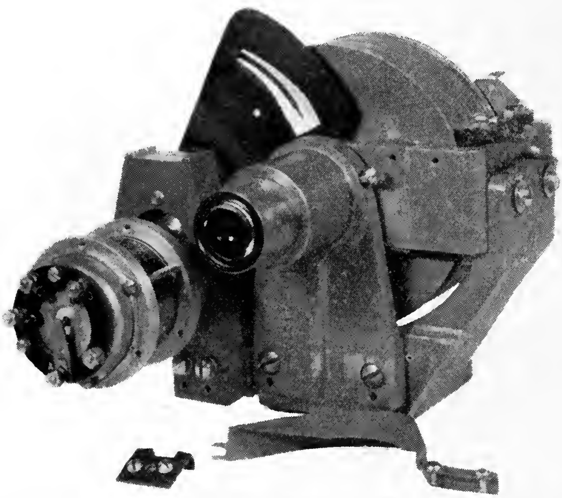

FIG. 6. Recorder masking unit; partial assembly showing mask.

could be supplied with two scales on the dial to give accurate indication for either condition.

The mask is cut in a milling machine in definite steps of 1 db., with the division between steps beveled and rounded. Test recordings have been made with and without modulation to determine whether the step mask moving rapidly will introduce any low-frequency noise, but none has been detected.

Test recordings give the expected film output levels within $\pm 1/2$ db. of the ideal values, when reproduced over the several types of commercial reproducing machines. At the present time, this degree of accuracy is generally conceded to be satisfactory.

Transmission Circuits.—The application of this equipment to a recording channel will vary with the arrangement of the transmission circuits at the particular installation, the desired operating routine, and the physical arrangement of equipment. Fig. 1 shows the general arrangement.

The recording attenuator is placed in a 500-ohm circuit just ahead of a bridging amplifier or equivalent, which feeds the film recorder equipped with the masking unit. An additional 10 db. of gain is necessary to overcome the 10-db. loss in the attenuator corresponding to normal recording with full-width track. The monitoring attenuator is also placed in a 500-ohm circuit, usually just ahead of the monitoring amplifier. Both potentiometers have no insertion loss on the zero step.

When the system is used for volume reduction, as previously discussed, the recording attenuator is switched out of the circuit and replaced by a 10-db. fixed pad as indicated by the diagram. An additional 10 db. of gain in the circuit balances the 10-db. pad loss to make the equivalent of a standard recording circuit. The monitoring attenuator is placed in the direct monitoring circuit so that it will reflect the relative output from the film and balance with the photoelectric cell monitor at all times.

When the system is used in the second manner to obtain additional noise reduction, the 10-db. fixed pad is replaced by the recording attenuator which decreases attenuation from 10 to 0, as the track width is reduced from 0 to 10 db. The monitoring attenuator is out of the circuit.

The use of the matting device permits a degree of control of output volume as well as a means of extending the signal-to-noise ratio on a release sound-track of the variable-density type, which can not be obtained to the same degree with any other type of sound recording. It can safely be said that this method adds an effective 5 db. to the signal-to-noise ratio of release prints without introducing any deterioration whatever in the sound quality. Its fairly wide application in the industry at the present time is sufficient proof that it is proving its worth in enabling the industry to give improved sound reproduction to the patrons of the theaters.

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[1] MILLER, W. C.: "Volume Control by the Squeeze-Track," *J. Soc. Mot. Pict. Eng.*, **XV** (July, 1930), No. 1, p. 53.

[2] ALBERSHEIM, W. J.: "Mathematical Relations between Grain, Background Noise, and Characteristic Curve of Sound-Film Emulsions," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Oct., 1937), No. 4, p. 417.

AN IMPROVED EDITING MACHINE*

J. L. SPENCE**

Realizing the need for better facilities for the film editor, a new type of editing machine radically different in many respects from devices hitherto used has been designed by J. F. Leventhal and the author. This machine performs all the operations desired by the film editor, such as matching, spotting, dubbing, synchronizing, *etc.*, as well as the ordinary functions of editing.

A new optical compensator makes it possible to construct a machine without intermittent movements or oscillating parts, and one in which the film glides silently

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*Presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Akeley-Leventhal Corp., New York, N. Y.

past the aperture without coming to a stop at each frame, as in the older machines. The machine has many other unusual features in addition to its great flexibility, and its simplicity of operation results in greater speed.

Threading is accomplished easily in a minimum of time; the film is merely laid in a track, a simple operation locks the retaining rollers into place, and the machine is ready to run. The film moves forward or backward with equal facility, and can be brought to a stop by a simple hand-control wheel. Footage and frame counters for both picture and sound afford an accurate check for length and for spotting sound and picture effects.

Since the machine operates very quietly, without distracting noises, it becomes, upon demand, a miniature projection room. The sound quality is exceptionally fine, and the power output of 10 watts is more than enough for normal requirements. Jacks are provided for several head-sets so that the machine may be used

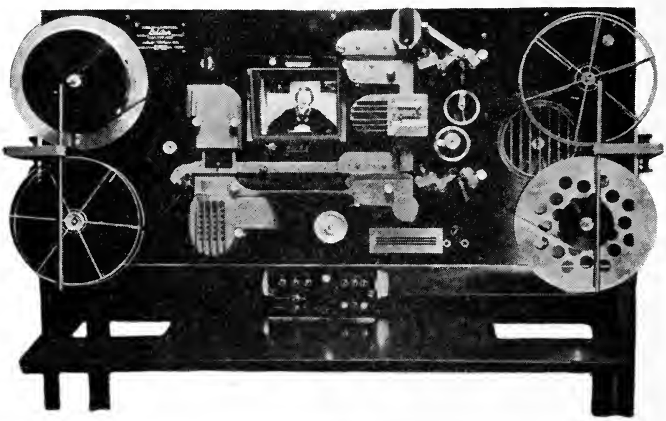

FIG. 1. Editing machine.

without disturbing others in the room. The sound is cut off automatically when the film is run backward.

Since there is no pressure on the film at any point along the picture area, and since no pressure pads or shoes are required as in standard projection apparatus, there is no tendency to develop scratches; and thus negative as well as positive films may be projected with perfect safety.

In an editing machine it is desirable to have a clear sharp picture of a size large enough to permit close inspection. The picture in this machine is projected upon a screen large enough to be viewed by several persons. Single-picture inspection is possible over any length of time without danger of overheating the film.

One of the novel features of the "editor" is a splicing attachment that permits making temporary splices rapidly and without losing frames, thus allowing the operator to make as many preliminary cuts as he desires.

A selector unit permits operating either the picture or the sound alone or together. A synchronizing arrangement is provided for the sound print channel so that the sound may be brought into synchronism with the picture *while running*.

This eliminates the necessity for rethreading and makes it possible for the operator easily to achieve synchronism in cases where "sync" marks are lost.

Unusual facilities are afforded for sound-track manipulation. Combined track and picture prints may be projected simultaneously with separate track prints. It is possible also to project a separate track print with the picture print in the same channel, thus affording an opportunity to hear several tracks at the same time that the picture is being edited.

The machine is provided with a variable-speed drive which can be controlled from 6 to 60 frames per second. This is in addition to a separate standard constant-speed drive of 24 frames per second.

Other features included new trouble-free "lift-off" take-ups, which prevent the film from breaking when taking up slack; reel spindle brake drums, which keep the film from overriding, regardless of reel speed; 2000-ft. capacity take-ups; special film "slip-off" flanges; and unit construction.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Communications

18 (Aug., 1938), No. 8

On Synthetic Reverberation (pp. 8–9) — S. J. Begun and S. K. Wolf

High-Frequency Correction in Resistance-Coupled Amplifiers (pp. 11–14, 22) — E. W. Herold

Automatic Equalization in Disc Recording (pp. 15–19, 24) — G. J. Saliba

Electronics

11 (Aug., 1938), No. 8

Television *V-F* Circuits (pp. 18–21) — E. W. Engstrom and R. S. Holmes

Practical Remote Amplifiers (pp. 25, 55) — R. W. Carlson

A Laboratory Television Receiver—II (pp. 26–29) — D. G. Fink

Institute of Radio Engineers

26 (Aug., 1938), No. 8

A High-Efficiency Grid-Modulated Amplifier (pp. 929–945) — F. E. Terman and J. R. Woodyard

A Unique Method of Modulation for High-Fidelity Television Transmitters (pp. 946–962) — W. N. Parker

High-Efficiency Modulation System (pp. 963–982) — R. B. Dome

A Phase-Opposition System of Amplitude Modulation (pp. 983–1008) — L. F. Gaudernack

Notes on the Impedance of a Carbon Microphone (pp. 1009–1010) — F. Offner

The Causes for the Increase of the Admittances of Modern High-Frequency Amplifier Tubes on Short Waves (pp. 1001–1132) — M. J. O. Strutt and A. van der Ziel

International Photographer

10 (Aug., 1938), No. 7

The Story of Kalart (pp. 9–11) — H. C. McKay

Studio Contacts Aid Lamp Design (pp. 15–18)

International Projectionist

13 (Aug., 1938), No. 8

Some Common Sources of Noise in Theatre Sound Systems (pp. 7–8, 10, 13) — A. NADELL

The Theory of Commutation (pp. 14–16)

Accident Prevention—Not Insurance—Is Key to Projection Room Safety (pp. 17–19) — T. P. HOVER

Kinotechnik

20 (Aug., 1938), No. 8

20 Jahre Zeitlupe (20 Years of High Speed Cameras) (pp. 197–199) — H. JOACHIM

Praktische Losungsmoglichkeiten für die raumakustische Behandlung von Filmateliers (Practical Treatment of Stereo-Acoustic Problem in Film Studios) (pp. 200–203) — H. JOACHIM

Pruffilme für Tonabtastspalte (Test Film for Sound Scanning Slit) (pp. 204–205) — H. ORLICH

Die Anwendung des Filmes als Forschungsmittel in Chemie, Physik and Technik (Motion Pictures for Experimental Work in Chemistry, Physics and Technology) (p. 207) — I. W. FORSTMANN

Lichtquellen der Kinoprojektion (Light Sources in Motion Picture Projection) (pp. 208–209)

Tonfilm "80,000 Bilder in einer Sekunde" ("80,000 Pictures Per Second" on Sound Film) (pp. 211–212)

Die Kinotechnik in der neuesten Patentstatistik (Patent Statistics for Motion Pictures) (p. 221) — E. BARTH

Philips Technical Review

3 (July, 1938), No. 7

Compression and Expansion in Transmission Sound (pp. 204–210) — V. C. HENRIQUEZ

Phenomena in Amplifier Valves Caused by Secondary Emission (pp. 211–216) — J. L. H. JONKER

An Apparatus for the Measurement of Scanning Speeds of Cathode Ray Tubes (pp. 216–219) — L. BLOK

Television and Short-Wave World

11 (Aug., 1938), No. 126

Continuous Film Television, a New Method (p. 452)

A Simplified Television Receiver Using a 1 In. Cathode-ray Tube (pp. 453–457) — D. E. OSMAN

The Baird Big-Screen Theatre Receiver, Complete Technical Details (pp. 459–460)

ABSTRACTS OF PAPERS FOR THE DETROIT CONVENTION

The following abstracts were received too late for inclusions in the October Journal and are published here for reference purposes:

"Technicolor Adventures in Cinemaland"; H. T. Kalmus, Technicolor Motion Picture Corp., New York, N. Y.

An historical review, on a somewhat technical basis, of the problems of the application of color processes, and particularly the Technicolor process, to the motion picture industry.

Standards Committee Report; E. K. Carver, *Chairman*

The items under consideration at the present time are as follows:

(*1*) Cores for 35-mm. and 16-mm. motion picture film have been given initial and final approval and will be published in an early issue of the JOURNAL. These cores are practically the same as the cine positive cores. The type of core, such as is ordinarily used for negative, with the key instead of the keyway, is considered non-standard.

(*2*) The question of sound-track dimensions is being held in abeyance awaiting a report of the Academy Committee investigating this subject.

(*3*) A preliminary drawing for 16-mm. sound-film sprockets has been given initial approval and has been sent out for criticisms.

(*4*) A definition of safety film, which limits the per cent of nitrogen in such film to 0.36 per cent and which adopts the so-called Lehman burning test and Lehman ignition temperature test, has been given initial approval.

(*5*) The question of the reduction ratio for 35 mm. to 16 mm. is in the hands of a sub-committee, but no action has yet been taken.

(*6*) The question of a universal perforation with the basic dimensions of the Bell & Howell and with the shape of the positive perforation is still under study. A report by Mr. Arnold is expected at this meeting.

(*7*) In regard to the term "variable-area" or "variable-width," an investigation by the Committee has shown that the term "variable-area" is preferred to the term "variable-width," but that both may be considered good usage.

"The Stability of the Viscose Type of Ozaphane Photographic Film"; A. M. Sookne and C. G. Weber, National Bureau of Standards, Washington, D. C.

Viscose Ozaphane, a new type of film with a base of regenerated cellulose sheeting, and having certain advantages for record use, was tested to determine its comparative stability. Its stability was compared with that of cellulose nitrate, and also with that of cellulose acetate, which is widely used for slide-films and which has been found to be a very stable material for preserving records in libraries. The viscose type of film apparently is not suitable for permanent records, but does appear to have properties to recommend its use for reading-room copies that can be replaced when they become unserviceable. The stability was determined by measuring changes in the chemical and physical properties under accelerated aging. The changes observed were increase in acidity and copper number, and decrease in viscosity, weight, and flexibility.

"The Evaluation of Motion Picture Films by Semimicro Testing"; J. E. Gibson, The National Archives, Washington, D. C., and C. G. Weber, National Bureau of Standards, Washington, D. C.

Test methods for the evaluation of motion picture film for permanent records require test specimens too large to be removed from certain archival films. To assist those charged with the preservation of such films in determining the quality and checking the condition of them, suitable semimicro methods were developed for acidity, viscosity, and residual hypo content. Specimens as small as 7 milligrams in weight, removed from the film with a small hand punch, gave satisfactory results for the purpose.

Report of the Studio Lighting Committee; C. W. Handley, *Chairman*

In a previous report the need of a catalog of studio lighting equipment was emphasized. A number of papers have been published describing in detail the various lamps and light-sources, but there has not been assembled in one paper a symposium of all types of equipment and light-sources. It is the intention of the Committee to correlate the published and unpublished data on motion picture studio light-sources in such form as to make this report a reference for complete information on the subject.

The various lighting units are numbered and briefly described. Photographs of popular lamps are shown. Tables give minimum and maximum beam divergences, carbon and bulb sizes. JOURNAL references are given as a key to further specific information on any lamp or illuminant. Data on light control devices and lamp filters is included.

"Latest Developments in Variable-Area Processing"; A. C. Blaney, RCA Manufacturing Co., Inc., Hollywood, Calif., and G. M. Best, Warner Bros. Pictures, Inc., Hollywood, Calif.

A series of curves is presented showing the photographic control of variable-area sound-tracks as obtained in commercial production at Warner Bros. Studio, and to show the wide tolerances in film processing that are permissible with class *A* push-pull recording, a factor of especial interest in connection with the daily production.

The results of a study of the technic involved in fine-grain photographic duplicating of variable-area sound-track for foreign release is also discussed.

"The Metro-Goldwyn-Mayer Semi-Automatic Follow-Focus Device"; J. Arnold, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

During recent years an important problem in major-studio cinematography has been that of following focus. Due to the shallow depth of field in modern lenses when used at maximum apertures, it is necessary to alter the focus frequently during the filming of a scene. In moving-camera shots, which are being used with increasing frequency, this problem is naturally aggravated, since both camera and players may move. The use of "blimped" cameras for sound pictures also aggravates the cameraman's problems, as finder parallax is greatly increased by placing the finder outside the camera "bungalow."

At the Metro-Goldwyn-Mayer Studio these problems have been simplified by the use of the semi-automatic follow-focus device. This consists of a finder which is both focused and pivoted to correct for parallax as the lens is focused. Individual cams coördinate the finder movement with the characteristics of any given lens.

So successful is this coördination that it is possible to determine whether or not an object is correctly focused in the camera by observing the object's focus and position in the finder. The device has been applied to all cameras used in production at the Metro-Goldwyn-Mayer Studio, and has over a period of several years proved to be accurate, dependable, and has facilitated production to a noteworthy degree.

"A Motion Picture Dubbing and Scoring Stage"; C. L. Lootens and D. J. Bloomberg, Republic Productions, Inc., North Hollywood, Calif., and M. Rettinger, RCA Manufacturing Corp., Hollywood, Calif.

A new dubbing (re-recording) and scoring (music recording) building recently completed on the Republic lot consists of the recording stage, a scoring monitoring room, projection booth, machine room, maintenance room, power room, and recording truck testing platform.

The recording equipment consists essentially of 2 complete RCA high-fidelity recording channels, with associated equipment of film-phonographs, test racks, power rectifiers, dubbing and scoring consoles, acetate recorder, and projection equipment.

The stage is of the live-end, dead-end type and has dimensions conforming to the recommended 1:2:3 ratio. The live end is provided with permanent side-wall and ceiling reflecting panels which increase the reverberation and diffusion. The remainder of the stage is treated with 4-inch rockwool battens, placed between the studs and retained in place by a dual muslin covering. The measured reverberation characteristic of the stage fulfills recommended requirements and is between 0.95 and 1.00 second for the frequency band of 540 to 7000 cps. The stage is also equipped with an 8-position console so that dubbing may be done in a room having theater sound characteristics.

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PROCEEDINGS OF THE SEMI-ANNUAL BANQUET

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

STATLER HOTEL
DETROIT, MICH.

NOVEMBER 1, 1938

Nearly 200 members and guests of the Society assembled at the Fall, 1938, Semi-Annual Banquet held at the Hotel Statler, Detroit, Mich., on November 1st. Guests at the speakers' table were Mr. G. R. Giroux, of the Technicolor Motion Picture Corporation; Mr. J. Frank, Jr., Secretary of the Society; Mr. A. S. Dickinson, Motion Picture Producers and Distributors of America, Inc.; Mr. H. Griffin, International Projector Corporation; Mr. E. P. Curtis, Eastman Kodak Company; Mr. G. F. Rackett and Dr. H. T. Kalmus, Technicolor Motion Picture Corporation; Mr. S. K. Wolf, President of the Society; Dr. K. S. Gibson, National Bureau of Standards; Mr. E. A. Williford, National Carbon Company; Dr. J. B. Engl, of Berlin, Germany; Mr. J. I. Crabtree, Eastman Kodak Company; Dr. A. N. Goldsmith, consulting engineer; and Mr. M. Hobart, Technicolor Motion Picture Corporation.

After introducing those seated at the speakers' table, President Wolf announced the results of the annual election of officers for 1938, and introduced Mr. E. A. Williford, President-elect, whose remarks follow:

Mr. Williford: Mr. Chairman, Honored Guests, Members of the Society, and Friends: I am not going to make a speech, but I think it would be really ungrateful of me if I did not express to you my deep appreciation of the kind ovation you have given upon the announcement of my election to the presidency.

Shortly after I was informed of my election, my education began. One of my very closest friends in the profession, one that I have

counted an intimate over the years, began to tell me what was wrong with the Society and with me, and there was much truth in what he said. From other sources since then I have learned that the job of being President of this independent thinking group of individualistic persons is a real job.

All I would like to say to you is this: those who are not as close to the scenes of what is going on in motion picture research and development probably think there isn't much progress being made. It looks very much like the same picture, sounds very much like the same sound; but those of us who are more active in it know that steady progress is going on and will go on for many years to come.

I only hope that in my administration of this Society's job, as President during the next two years, I can see the Society as an organization grow in usefulness and in service to the industry in the same manner in which our two particularly honored guests tonight have been instrumental in making progress in the industry itself.

Thank you all.

President Wolf next introduced the remaining officers- and governors-elect as follows:

Executive Vice-President	N. Levinson
Editorial Vice-President	J. I. Crabtree
Financial Vice-President	A. S. Dickinson
Convention Vice-President	W. C. Kunzmann
Secretary	J. Frank, Jr.
Treasurer	L. W. Davee
Governors	M. C. Batsel
	H. G. Tasker

The other officer and governors of the Society whose terms do not expire for another year were also introduced by President Wolf, as follows:

Engineering Vice-President	L. A. Jones
Governors	A. C. Hardy
	H. Griffin
	R. E. Farnham

During the introductions, Mr. J. Frank, Jr., the Secretary, called for a rising vote of appreciation for the work done by Mr. Wolf during his incumbency.

Next, referring briefly to the two awards made each year by the Society, namely, the Journal Award and the Progress Award, President Wolf asked Mr. E. A. Williford to read the citation on the work of Dr. Kasson Stanford Gibson, prepared by Mr. N. D. Golden:

CITATION ON THE WORK OF KASSON STANFORD GIBSON

For the second year in succession a member of the staff of the National Bureau of Standards of the Department of Commerce is to be honored with the Journal Award of this Society. In 1937, Dr. Dean Brewster Judd was given this honor. It is my privilege on

KASSON STANFORD GIBSON

behalf of the Journal Award Committee to announce that the paper by Dr. Kasson Stanford Gibson, "The Analysis and Specification of Color," appearing in the April, 1937, issue of the Society's JOURNAL, has won this award for 1938.

It is appropriate to review briefly Dr. Gibson's career and scientific background. Dr. Gibson was born at Afton, N. Y., on January 7,

He received his early education in the public schools of Norwich, N. Y., graduating from the High School in 1908. In 1912 he received his Bachelor of Arts degree from Cornell University and in 1916 his degree of Doctor of Philosophy from the same University. Dr. Gibson was also elected to the honorary societies of Phi Beta Kappa and Sigma Xi while at Cornell, and was an instructor in the Department of Physics from 1912 to 1916.

After Dr. Gibson received his Doctor of Philosophy at Cornell University, he joined the staff of the National Bureau of Standards in 1916 in the Colorimetry and Spectrophotometry Section as an Assistant Physicist. In 1919 he rose to the position of Associate Physicist, in 1922 he became a Physicist, and in 1928 a Senior Physicist; in 1933 he was made Chief of the Section and in 1936 Principal Physicist, the position which he is now holding.

Dr. Gibson has published more than forty scientific papers and reports, in the Journals of the Optical Society of America, American Physical Society, Society of Motion Picture Engineers, Illuminating Engineering Society, and American Oil Chemists Society, in the Journal of Research of the National Bureau of Standards, and in the Proceedings of the Signal Section of the Association of American Railroads, the International Commission on Illumination, and the International Congress of Photography.

Dr. Gibson is a Fellow, in the American Association for Advancement of Science, and the American Physical Society, and holds membership in the Optical Society of America, having been an associate editor of their Journal since 1927, a member of their Board of Directors since 1935 and a Vice-President of the Optical Society since 1937.

Dr. Gibson is also associated with other scientific organizations, among which are the Illuminating Engineering Society, American Oil Chemists Society, Washington Academy of Sciences, and the Philosophical Society of Washington.

Dr. Gibson is a recognized authority in the field of colorimetry, spectrophotometry, heterochromatic photometry, artificial daylight, and spectral filters. It is with pleasure that I present to the Society of Motion Picture Engineers Dr. Kasson S. Gibson as the recipient of the 1938 Journal Award.

After receiving the Journal Award certificate from President Wolf, Dr. Gibson responded as follows:

DR. GIBSON: Mr. Chairman, Ladies, and Gentlemen: I appreciate this honor very much indeed. When the Chairman of your Journal Award Committee notified me that my paper had been selected for this honor, he spoke about the complexity of the subject of color. One of the reasons why the subject seems so complicated is because of the different ways in which the word "color" is used by various groups. You may be interested in some of these ways.

This afternoon, for example, I gathered that to the motion picture engineers color means a departure from black and white, and this usage of the word is consistent with that of the artist, who divides his palette into colors and grays. But I imagine if some of the ladies in the audience were asked the colors of their dresses they would not hesitate to say "white" or "gray" or "black," if the dresses didn't happen to be "cactus green" or "glamor gold" or "rhythm red."

The psychologist defines color as a sensation or perception, but the physicist talks about the reflection and absorption of colors; the chemist discusses whether or not colors obey Beer's law, and we have the paint manufacturer buying and selling colors by the pound, dry colors at that.

Then we have the expression "pure color." To the physicist that means that the light is of a single wavelength; to the dye chemist it means an unadulterated dye; to the psychologist it means one of the unitary hues; whereas to the designer it means maximum departure from gray.

The word "white" is used to refer to the color of daylight or sunlight or to any source that has a continuous spectrum; or it may refer to the color of the tablecloth, or to the color of water, as when certain liquids are designated as "water-white."

When my son comes home from school he tells me that his teacher says that black is the absence of color. That usage is certainly contrary to the one that designates the black race as the "colored race." Finally, as many of you know, we have the theoretical black body, which may be any color—red, orange, yellow, white, or blue, depending upon the temperature.

I therefore felt highly complimented when the Chairman of the Committee referred to the clarity with which I presented the subject of color. However, I assume the award was given for writing and not for talking, and I am therefore going to conclude these remarks immediately.

I wish to thank the Journal Award Committee and the members of

the Society for this honor. I deeply appreciate it, as I have said, and it will be a source of great encouragement to go forward with our work in color at the National Bureau of Standards.

PRESIDENT WOLF: The highest award that the Society can offer to its members is known as the Progress Medal. This award goes to the person selected by the Committee who has contributed most to the science and art of our industry. We have the pleasure tonight to present to you Mr. G. F. Rackett, who will read the citation for the recipient of the Progress Award Medal:

HERBERT THOMAS KALMUS

CITATION ON THE WORK OF HERBERT THOMAS KALMUS

Motion pictures are unique in being a commercialized art form whose combination of applied science and engineering, together with the modern creative arts, has engaged the widespread interest of the public over the world. It is not unexpected that such a field of endeavor would invite the energies of outstanding experts in the sciences, engineering, and the arts, with the consequence that per-

formance meriting distinction becomes distinction indeed. In the three Progress Awards that have been made by the Society of Motion Picture Engineers, its Progress Award Committee has exhibited judgment that merits the commendation of the motion picture industry and it is therefore with a feeling of pride and humility that I proceed with the great privilege of presenting the citation of the fourth recipient of the Progress Award medal, Dr. Herbert T. Kalmus. In addition to having a knowledge born of direct contact with the outstanding achievements of Dr. Kalmus during recent years, together with a review of his broad achievements of record previous to that period, it has been my further privilege to know him in work and in play, to become acquainted with his leadership, and to enjoy his friendship.

Dr. Kalmus is a rugged product of New England, with a background characterizing the stability, conservatism, and modesty of that older section of our country. This background took him to the Massachusetts Institute of Technology from which he received his Bachelor of Science Degree in 1904. It is noteworthy that, during his tour of education at M. I. T., among other things Dr. Kalmus was called upon to perform some consulting work in connection with the construction of the aqueduct which was later to supply the City of New York with water. The problem was solved with a directness and practicality characteristic of his subsequent achievements.

As a graduate fellow of the Massachusetts Institute of Technology Dr. Kalmus studied in Europe, first at the University of Berlin under Professors Paul Drude, Walter Nernst, and J. H. Vant Hoff, and subsequently at the University of Zurich where he completed his work for a degree of Doctor of Philosophy. His thesis was an extensive experimental and theoretical study of "Electrical Conductivity and Viscosity of Fused Electrolytes." Returning to M. I. T., Dr. Kalmus spent the next six years as Research Associate in the laboratory of Professors A. A. Noyes and H. M. Goodwin, conducting experimental investigations in the field of physical chemistry. Independently he published papers on various subjects in a wide field, including destruction of bacteria by radiation from electrical discharges, electromotive forces set up in the human body by emotions, etc.

In 1913 Dr. Kalmus left the Massachusetts Institute of Technology in response to an invitation to join the faculty of Queen's University, Kingston, Ontario, where he became Professor of Physics. Out-

standing performance was reflected in his appointment as Director of Research, laboratory of electrochemistry and metallurgy for the Canadian Government which led into important activities in the industrial field. His study of the then relatively little known metal, cobalt, was covered by six articles published by the Canadian Bureau of Mines, laying the groundwork for practical industrial uses of the metal. Other industrial applications included the recovery of metallic values of waste materials by centrifuging and the production of alumina from nephalene cyanates.

Interests seeking an equivalent of alundum and carborundum for the rapidly narrowing abrasives supply called on Dr. Kalmus to solve the problem. His work in this field, together with some patents resulting therefrom, were the basis of The Exolon Company which Dr. Kalmus developed to an important and profitable business, becoming successively vice-president, treasurer, and president. Dr. Kalmus retired from this business when its technical problems were well in hand and it had become an important factor in the abrasive industry. With Dr. D. F. Comstock, Dr. Kalmus organized a firm of consulting engineers, Kalmus, Comstock & Wescott, Inc., which investigated a considerable number of live industrial problems. Some of them were undertaken and solved with extraordinary facility.

One of these problems had long engaged the attention of many scientists, experimenters, and engineers in their quest to relieve the drabness of the black and white motion picture from its monochrome limitation and to bring to the screen the naturalness of color. Out of this endeavor Technicolor was born and has engaged the principal attention of Dr. Kalmus for the past fifteen years.

We were both entertained and instructed today when some phases of the romance of this development were described by Dr. Kalmus in his paper, "Technicolor Adventures in Cinemaland."

In charting the course of Technicolor so as to develop a practical engineering solution to the problems of putting natural color on the screen, Dr. Kalmus soon found much necessary work to be done not apparently connected with color. For it must be borne in mind that in the neighborhood of 1920 the state of black and white motion pictures was still relatively undeveloped, for cameras, photographic materials, processing and projection equipment were in an elemental state. Furthermore, at that time available facilities were extremely limited and had to be created as work proceeded.

But Dr. Kalmus had an ideal, and, more importantly, the ability

to analyze the technical aspects of the problem, to develop and supervise a staff of scientists, experimenters, and engineers exploring and solving these problems in a well conceived and directed plan, travelling always toward the ultimate goal of natural color in a form practical for use in the motion picture theater. The story of Technicolor's achievement, first in exploring and ultimately abandoning additive methods of color photography, is generally known. This was followed by the exploration and development of a two-color subtractive process which remains today as the most practical solution to this intermediate stage of bringing natural color to the screen. This problem, however, was only completed to be abandoned, for it was but a step along the road to the problem visualized by Dr. Kalmus, which was not to bring part of the spectrum to the screen but to bring all of the spectrum to the screen. His comprehensive leadership is perhaps no better typified than in the wisdom and foresight which enabled him to authorize and direct the development of the first practical three-color subtractive process for motion pictures during the post-depression period when limited budgets and an industry busy with the developments of new technics in an expanding art form had little time, interest, or money to experiment in the color medium. In his accomplishment Dr. Kalmus is responsible not only for the leadership of the men who were directly responsible for the technical development and solution of this complex problem, but at the same time with a comprehensive view of the economics of the problem whose business aspects are fully as complex and demanding as the technical requirements. It is seldom in the annals of technical development that the ability to direct the business, economic, and technical aspects of a highly specialized enterprise have been successfully carried out by a scientist whose ability reached equally into the fields of technology, economics, and business.

This comprehensive ability invited and merited the support of business and financial leaders whose confidence in the record of Dr. Kalmus made available to him the necessary large units of finance to undertake this extensive work which embraced the development of a process and the construction of cameras, photographic equipment, manufacturing plants, and corollary facilities. These have developed into a Technicolor of international proportions whose principles and policies have reflected his leadership and have merited the outspoken commendation, not only of the motion picture industry, but of allied business interests.

The confidence reposed in Technicolor by the important producers of the motion picture industry is perhaps best exemplified by Technicolor's stewardship of the negative of major productions in which reside large investments whose return is dependent upon the rapid and reliable production of high quality prints. The organization of Technicolor, capable of assembling and delivering answer prints of twelve-reel feature pictures in approximately one week, the Technicolor plant in Hollywood with capacity of 130,000,000 feet per year and its plant in England with capacity of more than 25,000,000 feet per year, represent but a part of the enterprise which rests on the shoulders of Dr. Kalmus.

This citation would not be complete, however, if it were limited to an exposition of the past achievements of Dr. Kalmus. In engineering we plot progress curves, not entirely because we are interested in what has happened but also because we are interested in the indication of these curves as to what will happen. The progress curve of Dr. Kalmus leaves little doubt not only that it will continue to maintain its upward gradient but that its form will be exponential. This citation, then, is of a man whose achievements have been great and whose unspoken promise of achievement is looked forward to by all of his associates whose highest praise is probably couched in their frequent reference to the fact that he has never let them down. In his growing stature of technical and business leadership, Dr. Kalmus casts a lengthening shadow which, singularly enough, appears as a rainbow whose arc plots its points of natural color on the screens of the motion picture theaters of the world.

At the conclusion of Mr. Rackett's citation, the Progress Medal of the Society for 1938 was presented to Dr. Kalmus by President Wolf. Dr. Kalmus responded as follows:

DR. KALMUS: Mr. President, Mr. Rackett, Members of the Society, Friends: Frankly I was surprised when Dr. Goldsmith notified me some weeks ago that the award of the Progress Medal of the Society for 1938 had been made to me. I am greatly honored and I wish first to express my deep appreciation to the members of the Committee who made the recommendation, to the members of the Board of Governors of the Society who approved the recommendation, and to the Society itself.

This award has been made but three times before—to Dr. Edward C. Wente for the volume and importance of his contributions to

motion picture art; to Dr. C. E. Kenneth Mees for outstanding and distinctive achievement in the field of motion picture photography; and to Mr. Edward W. Kellogg for outstanding achievement in motion picture technology.

Tonight, in so graciously conferring this medal upon me, our President has stated that it is for pioneer activities, broad planning, and important contributions to the development of color motion picture photography. Mr. Rackett, too, has been most liberal in his praise of my efforts.

To me all this signifies remarkable breadth of view among those gentlemen who are shaping the destinies of this great Society. As further evidence I quote from Mr. Kellogg's remarks upon receiving the award a year ago: ". . .It is only proper that we technical men should express our recognition of the fact that contributions to progress take many forms and that while the working out of purely technical problems is an essential part, there are other equally important roles. Directors and managers who express their faith in the future make progress possible by appropriating liberal sums to research, and by backing their men through periods of little apparent accomplishment. . . . Executives who see that emphasis is placed upon the most valuable projects and who can keep enthusiasm alive in their organization, engineers who put developments into commercial shape, salesmen who push the best things, workers in the field who find the best ways of using things and give us the benefit of their experience—all these play an indispensable part in furnishing the public with something better than it had before. . . ."

It was such a point of view as this which gave me the courage some years ago to abandon the relatively snug situation of conducting physical, chemical, and metallurgical research within the more or less cloistered wall of the University and to a considerable extent for the Government, in order to tackle the job of planning, managing, and financing a number of technical ventures.

I organized and had general direction of a group of scientists and engineers whose researches and experiments yielded the first two-color, additive Technicolor process. This was about 1916. Some twenty years later our very distinguished member, Dr. Mees, encouraged me not a little by remarking: "I don't know which is the greater achievement, the work you have done in planning, managing, and financing Technicolor through all these difficult years, or the actual scientific and technical progress that has been made."

It is especially gratifying to me that the story of my work should be presented here tonight by Mr. Rackett, who has been in the thick of the Technicolor fray with me during the last ten years, and to whom I give the greatest credit for having solved many perplexing engineering, operating, and plant personnel problems. The solution of these practical problems has made possible higher quality coupled with lower costs and has enabled us in Technicolor to employ as a part of our day-to-day print manufacturing procedure certain inventions of our research department which otherwise might have remained merely paper patents.

Some weeks ago my good friend, Mr. Albert W. Hawkes, President of Congoleum Nairn, Inc., and a director of the Technicolor companies, sent me a copy of an article from the August, 1938 issue of *Advertising Age*. It is too long to quote completely, but with apologies to Mr. F. C. Bierne, its author, I am taking the liberty of paraphrasing a portion of it as follows:

"An executive has to decide what is to be done; to tell somebody to do it; to listen to reasons why it should not be done, why it should be done by somebody else, or why it should be done in a different way; to follow up to see if the thing has been done; to discover that it has not been done; to listen to excuses from the person who should have done it; to follow up a second time; to discover that it has been done but incorrectly; to point out how it should have been done; to conclude that as long as it has been done it might as well be left as it is . . .; to consider how much simpler or better the thing would have been done had he done it himself in the first place; and finally to reflect sadly that if he had done it himself he would have been able to do it right in twenty minutes but that as things turned out he himself spent two days trying to find out why it took somebody else three weeks to do it wrong."

I admit that some days did seem like that and still do but they are the exceptions not the rule for as I look back over the years of struggle with Technicolor I am convinced that the choice of well-trained, able, resourceful, loyal associates and assistants, with whom no such procedure as that was necessary, was largely responsible for the progress that has been made.

In the earliest years and during the development of the two-color process, up to approximately the time of *The Black Pirate*, Daniel F. Comstock, W. Burton Wescott, and the late Professor E. J. Wall played leading parts, with J. A. Ball, E. A. Weaver, and the late

Leonard T. Troland assisting them. Later Ball and Troland carried on from where Comstock and others left off. In the transition to the present three-color process, Ball took the lead, whereas Troland was responsible for our earliest excursions into the field of monopack.

Through the years Natalie Kalmus and George Cave and more recently Robert Riley and Henri Jaffa have had much to do in the field of preparation, color direction, and photography, to bring together, smoothly and practically, the essential conditions for Technicolor and the existing practical procedure in the studio and on location. Mr. Frank R. Oates and Mr. Kay Harrison are carrying on in England, and I have already referred to the exceptional work of Mr. Rackett and his staff.

And last but by no means least, I would acknowledge the tremendous support which our endeavors have at all times received from Eastman Kodak Co. No account of Technicolor would be accurate without acknowledgment to Dr. Mees, to Mr. E. P. Curtis, and to Mr. John Capstaff of constant inspiration and much practical help.

And so, Mr. President, with full credit to all my associates and assistants, both within and without the Technicolor organization, except for whose able performance and splendid loyalty all leadership, whether planning, managing, selling, or financing would have gone for naught, and in the splendid broad spirit of this Society as exemplified by the language of the award itself and by the remarks I have quoted, I accept this medal, together with the extraordinary honor which it signifies, and the opportunity which it bespeaks for continuing in the job of trying to make better and less expensive motion pictures in color.

TECHNICOLOR ADVENTURES IN CINEMALAND*

H. T. KALMUS**

Summary.—*An account of some of the highlights in the history of the development of the business of Technicolor Motion Picture Corporation primarily from the point of view of its contact with motion picture producers, distributors, and exhibitors; incidental to which is an account of the development and growth of the various Technicolor processes from a semi-technical point of view but with special reference to practical application in the motion picture industry.*

Webster defines adventure as *chance of danger or loss; the encountering of risks; a bold undertaking, a daring feat; a remarkable occurrence or experience, a stirring incident; a mercantile or speculative enterprise of hazard; a venture.* The excursions of Technicolor into the domain of the producers, distributors, and exhibitors of motion pictures have been all of these.

Technicolor has manufactured and shipped prints of many hundreds of productions (during 1937 alone of over 350 subjects for some fifty different customers including more than twenty features) and since some phase of adventure usually develops during the photography or printing of any production, it is clear that this account does not pretend to be complete.

Nor are the events described in detail necessarily those of greatest importance. The writer having played a continuing part will no doubt unduly emphasize some which he found particularly interesting, whereas with the passage of time others only lightly touched upon or omitted may be found to be of greater significance. However, it is hoped that this paper may be a fitting preliminary to a more ambitious one which I have been asked to prepare, reviewing the progress of color cinematography over the past quarter of a century, with special reference to the contributions of Technicolor.

Early in the development of any color process, two decisions of

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** Technicolor Motion Picture Corp., New York, N. Y.

policy must be made: first, how far will it permit departure from standard equipment and materials, and, second, how will it attempt to divide the additional requisites of recording and reproducing color between the emulsion maker, the photographic and laboratory procedure, and the exhibitor's projection machine. Technicolor assumed at the outset that special cameras and special projectors were permissible, provided raw film of standard dimensions were employed.

The earliest Technicolor laboratory was built within a railway car. This car was completely equipped with a photochemical laboratory, darkrooms, fire-proof safes, power plant, offices, and all the machinery and apparatus necessary for continuously carrying on the following processes on a small commercial scale; sensitizing, testing, perforating, developing, washing, fixing and drying negative; printing, developing, washing, fixing and drying positive; washing and conditioning air; filtering and cooling wash water; examining and splicing film; and making control measurements and tests. In 1917 the car was rolled over the railway tracks from Boston, Massachusetts, where it was equipped, to Jacksonville, Florida, where the first Technicolor adventure in feature motion picture production was to take place. The camera was the single-lens, beam-splitter, two-component type, without the refinements which came later. The picture was *The Gulf Between*, with Grace Darmond and Niles Welch playing the leads. Technicolor was the producer. Dr. D. F. Comstock, Mr. W. B. Wescott, Professor E. J. Wall, Mr. C. A. (Doc) Willat, Mr. J. A. Ball, Mrs. Kalmus, and I were all on the job. The process was two-color, additive, standard size frame, and hence demanded a minimum of the laboratory procedure.

During the progress of this production, February, 1917, I was invited by the American Institute of Mining Engineers to deliver a lecture at Aeolian Hall, New York, to expound the marvels of the new Technicolor process which was soon to be launched upon the public and which it was alleged by many could hardly do less than revolutionize their favorite form of entertainment.

The Gulf Between had been preceded by *The Glorious Adventure*, a feature picture made in England by the Kinemacolor Process. Since Kinemacolor photographed the color components by successive exposure, it was nothing for a horse to have two tails, one red and one green, and color fringes were visible whenever there was rapid motion. The Technicolor slogan was two simultaneous exposures from the same point of view, hence geometrically identical components and

no fringes. At that time hundreds of thousands were being spent by others trying in impossible ways to beat the fringing of successive exposures and the parallax of multiple lenses.

I thought the Technicolor inventors and engineers had a practical solution, commercial at least temporarily, so I marched bravely to the platform at Aeolian Hall. It was a great lesson. We were, of course, introducing the color by projecting through two apertures, each with a color filter, bringing the two components into register on the screen by means of a thin adjusting glass element. Incidentally, Technicolor had to invent and develop a horizontal magnetically controlled arc which gave one-third more light for the same current than the then-standard vertical arcs and which could be relied upon for constancy of position of the source. This latter was vitally important with a double aperture. During my lecture something happened to the adjusting element and, in spite of frantic efforts of the projectionists, it refused to adjust. And so I displayed fringes wider than anybody had ever before seen. Both the audience and the press were very kind but it didn't help my immediate dilemma or afford an explanation to our financial angels.

Arrangements were made with Messrs. Klaw and Erlanger to exhibit *The Gulf Between* by routing the photoplay one week each in a group of large American cities. During one terrible night in Buffalo I decided that such special attachments on the projector required an operator who was a cross between a college professor and an acrobat, a phrase which I have since heard repeated many times. Technicolor then and there abandoned additive processes and special attachments on the projector.

As early as 1918 Technicolor had in mind two principal methods of attacking the color problem. Dr. Leonard T. Troland, who, at the time of his death, was Director of Research of Technicolor Motion Picture Corporation, had done some important pioneer work on the Monopack process. Some of his inventions were embodied in numerous patent claims which have been issued and which were intended broadly to cover the multi-layer method both for taking and printing. The other Technicolor attack was by the imbibition method. Both Monopack and imbibition were obviously capable of ultimate development into multi-component processes, but since imbibition seemed to load more of the problems on the laboratory and relatively less on the emulsion maker, we pursued it with the greater vigor.

A first approximation to the Technicolor imbibition method consisted of two gelatin reliefs produced upon thin celluloid which were glued or welded together back to back and dyed in complementary colors. Combined with the Technicolor two-component cameras, this method provided an immediately available system (1919–21) capable of yielding two-component subtractive prints. A small laboratory or pilot plant was built in the basement of the building occupied by the Technicolor engineers, Kalmus, Comstock & Wescott, Inc., on Brookline Avenue, Boston, Mass.

In 1920 Judge William Travers Jerome first became interested in Technicolor; he brought as associates the late Marcus Loew, Nicholas M. Schenck, now President of Loew's, Inc., and Joseph M. Schenck, now Chairman of the Board of Twentieth Century Fox, Inc.

Both Joseph and Nicholas Schenck have on many occasions been most helpful to Technicolor by giving practical advice to Judge Jerome and to me, but at no time more so than when it was decided to produce the photoplay which was later called *The Toll of the Sea*. This was the first Technicolor production by the subtractive method. It was photographed in Hollywood under the general supervision of Mr. Joseph M. Schenck, Chester Franklin, Director, Anna May Wong, lead, and J. A. Ball, Technicolor cameraman.

Mr. Nicholas Schenck arranged for the release of *The Toll of the Sea* by Metro-Goldwyn-Mayer. The first showing was given at the Rialto Theater in New York, the week of November 26, 1922. Letters of praise were received from Maxfield Parrish, Charles Dana Gibson, and other artists. But because of insufficient laboratory capacity we were not able to supply prints fast enough to follow this up immediately and not until 1923 was the picture generally released in the United States. It grossed more than $250,000, of which Technicolor received approximately $165,000.

The prints of *The Toll of the Sea* were manufactured in the original pilot plant on Brookline Avenue, at a manufacturing cost of about 27 cents per foot.

Every step of the Technicolor work in *The Toll of the Sea* was carefully watched by the executives of the industry. Rex Ingram, who was in the midst of producing *Prisoner of Zenda*, wired Mr. Loew for permission to scrap everything he had done in black and white on that picture and start over again in color. D. W. Griffith wanted to produce *Faust* and Douglas Fairbanks telephoned about producing a feature.

Our first adventure in Hollywood seemed successful! We were told that with prints as good as we were manufacturing if offered at 8 cents per foot the industry would rush to color.

But, thus far we had made only inserts and one feature production, *The Toll of the Sea,* of which Technicolor was itself the producer. We had no adequate means of giving rush print service in Hollywood, and we were charging 20 cents a foot for release prints. It was another matter to convince a producer to employ the Technicolor company to photograph and make prints of a production at his expense and risk and under the conditions which prevailed in the motion picture industry.

Meanwhile Technicolor Plant No. 2 was being built in Boston in a building adjoining the one containing the Pilot Plant. It had a capacity of about one million feet of prints per month and cost approximately $300,000. And in April, 1923, the late C. A. Willat, in charge, J. A. Ball, Technical Director, G. A. Cave, Assistant Technical Director, were sent from Boston to establish a small Technicolor laboratory and a photographic unit in Hollywood. This was established in a building in Hollywood rented for the purpose.

In November, 1923, Mr. Jesse L. Lasky and I finally agreed upon the terms of a contract between Technicolor Motion Picture Corporation and Famous Players Lasky Corporation for the production of *The Wanderer of the Wasteland.* We were told by Mr. Lasky that they had appropriated not more for this picture than they would have for the same picture in black and white. Also that the time schedule allowed for photographing was identical with what it would have been in black and white. The photography was to be done by our cameras in the hands of our technical staff, but following a budget and a time schedule laid out for them by Famous Players. Rush prints and the quality of negative were to be checked by them each day. During the six weeks of photography our entire staff worked from early morning to late at night, including Sundays and holidays. At one time we were accumulating negative which we did not dare to develop because of inadequate facilities in our rented laboratory. A few of us in Technicolor carried the terrorizing thought that there was no positive assurance that we would finally obtain commercial negative, and that the entire Famous Players investment might be lost. However, Mr. Lasky was not permitted to share that doubt. His confidence and help during the darkest hours were really marvelous and finally the cut negative emerged satisfactorily. We delivered ap-

proximately 175 prints which were shown in several thousand theaters over the country. These prints were billed at 15 cents a foot, for which Technicolor received approximately $135,000. Some of these prints were made in the pilot plant, but more of them were made in Plant No. 2 which was now being run by operators we had trained.

Nevertheless there were reasons why we could not obtain a volume of business. Every producer in Hollywood knew that the first important production by the Technicolor process under actual motion picture conditions and not controlled by the Technicolor company, had just been completed by Famous Players Lasky Corporation. A considerable group of producers expressed themselves as interested, but were waiting to see the outcome. Another group believed the process to be practical and might have paid our then price of 15 cents a foot, but considered it impracticable to send the daily work to Boston for rush prints.

A small plant, primarily for the purpose of developing negative, making rush prints, and providing a California headquarters was installed at 1006 North Cole Avenue, Hollywood, in a building erected for our purposes. A large part of the equipment was built by our engineers in Boston and shipped to California. The installation was ready for operation about the middle of the year 1924.

Neither *The Toll of the Sea* nor *The Wanderer of the Wasteland*, nor any of the inserts made until the middle of 1924 had given us experience photographing with artificial light. We were therefore very glad to obtain an order for an insert in a production directed by Mr. George Fitzmaurice, called *Cytherea*, photographed in the United Studios lot in Hollywood, giving us our first experience in photographing an interior set on a dark stage. Mr. Fitzmaurice was delighted with the results.

In the Fall of 1924 we had six men and four cameras working in Rome on the Metro-Goldwyn-Mayer production, *Ben Hur*.

One of the great adventures of Technicolor in Cinemaland and a milestone in its progress was in the photography, print manufacture, and exhibition of Douglas Fairbanks' *The Black Pirate*. Mr. Fairbanks had the idea that the screen had never caught and reflected the real spirit of piracy as one finds it in the books of Robert Louis Stevenson, or the paintings of Howard Pyle, and that he could catch it by the use of color. He said, "This ingredient has been tried and rejected countless times. It has always met overwhelming

objections. Not only has the process of color motion picture photography never been perfected, but there has been a grave doubt whether, even if properly developed, it could be applied, without detracting more than it added to motion picture technic. The argument has been that it would tire and distract the eye, take attention from acting, and facial expression, blur and confuse the action. In short it has been felt that it would militate against the simplicity and directness which motion pictures derive from the unobtrusive black and white. These conventional doubts have been entertained, I think, because no one has taken the trouble to dissipate them. A similar objection was raised, no doubt, when the innovation of scenery was introduced on the English stage—that it would distract attention from the actors. Personally I could not imagine piracy without color. . . . "

But Mr. Fairbanks' attorneys pointed out that this production would cost a million dollars, and asked what assurance there was that Technicolor would be able to deliver prints, much less satisfactory prints. This difficulty was finally resolved by making a tripartite agreement in which the engineering firm of Kalmus, Comstock & Wescott, Inc., which still had the pilot plant in the basement of its building, agreed under certain conditions that it would deliver the prints in case Technicolor company failed. There was great discussion as to the color key in which this picture would be pitched. We made test prints for Mr. Fairbanks at six different color levels, from a level with slightly more color than black and white, to the most garish rendering of which the Technicolor process was then capable. Mr. Fairbanks set to work on the shore of Catalina Island and off that shore on his pirate ship, with four of the seven Technicolor cameras then in existence, to capture moods after the manner of impressionistic painting. The picture was released through United Artists in 1925. So far as audience reaction, press reviews, and box-office receipts were concerned, it was a triumph from the start, but for the Technicolor company it was a terrible headache.

Technicolor was still making the double-coated cemented together relief prints, so that the red and green images were not quite in the same plane, and the pictures didn't project too sharply on the screen. This double-coated film is considerably thicker than ordinary black-and- white film, with emulsion on both sides which tends to make it cup more readily and scratch more noticeably than black- and- white film. And the cupping could occur in either direction, more or less at

random. Judging from the complaints, at each such change in the direction of cupping, the picture would jump out of focus. We sent field men to the exchanges. We provided these men with a supply of new prints to replace the cupped ones in the theaters, in order that the latter might be shipped back to our laboratory in Boston for decupping. The newly decupped prints were temporarily satisfactory; the picture was a great success, but our troubles never ended.

It had been clear that this double-coated process was at best but a temporary method, and the work of developing a true imbibition process was being pressed in our research department.

But unfortunately the imbibition process was not ready for *The Black Pirate*, or for *The Wanderer of the Wasteland*.

Early in 1925 Mr. Sydney R. Kent, then head of distribution of Famous Players Lasky Corporation, said: "We have concluded not to do more Technicolor pictures for the present, for two reasons: first, because we have had a great deal of trouble in our exchanges due to the fact that the film is double-coated and consequently scratches much more readily than black and white, with the necessity of having to order more replacements, and it is an added bother to our operators; and, second, because the cost is out of all proportion to its added value to us. We paid $146,000 additional for *Wanderer* prints. We understand that you need volume to get your costs down. At an 8-cent price we would be interested to talk volume."

Evidently Technicolor needed the single-coated imbibition prints and volume to lower the price to meet his conditions.

Meanwhile Mr. Nicholas Schenck, then President of Loew's, Inc., was advising us to produce a picture ourselves, to prove both quality and costs.

And so in 1926–27 I once more found myself explaining to the directors of Technicolor that I always had believed and still believed very thoroughly in the ultimate success of the Technicolor project, always provided, however, that it was recognized by all the Directors to be a tremendously difficult undertaking technically and one which requires business sagacity and financial endurance. These directors, including the late Wm. Travers Jerome, the late Wm. Hamlin Childs, the late A. W. Erickson, the late Wm. H. Coolidge, the late Thomas W. Slocum, James C. Colgate, Eversley Childs, and Alfred Fritzsche, had many earlier reminders of the necessity of financial endurance. Prior to 1926 over two and one-half million dollars had been spent, but this time I was not calling for money for cameras and

printers, for imbibition machines and research salaries; it was to go into production. When they asked me what I knew about production, I frankly told them nothing, but at least I could start from scratch without some of the fixed ideas and prejudices concerning color that some of the Hollywood producers seemed to have accumulated. I wanted to make short subjects, not primarily to make money as a producer, but to prove to the industry that there was nothing mysterious about the operation of Technicolor cameras, that the transition from what the eye saw to what the emulsion recorded was susceptible of reasonable control through understanding, that black and white cameramen could easily be trained to light for Technicolor cameras, that talented art directors could readily begin to think in terms of color, that rush prints could be delivered promptly, and generally that the job could be done efficiently and economically, utilizing but not minutely imitating black- and white-experience.

The first short we produced was a story of the creation of the American flag, an episode involving George Washington and Betsy Ross. George M. Cohan probably never produced anything more certain of applause than when George Washington unfurled the first American flag in glowing color. Another subject was the divorce episode of Napoleon and Josephine, photographed in November, 1927, which was booked all over the world as a companion short to Charlie Chaplin's then tremendously successful production, *The Circus*. We made twelve of these two-reelers, an experience which established the fundamentals of our studio service both in the camera and color control departments, and altogether disclosed the answers to a multitude of practical questions which have served us no end since that time.

They were produced economically and yet we were continually praised about them by Metro who distributed them. In my opinion Technicolor would not have survived without the experience of this series of short subjects.

Our friends and customers both in Hollywood and New York praised and applauded these short subjects, *but* they were only shorts. Mr. Nicholas Schenck advised us to produce a feature production which Metro would distribute.

I had been much impressed with a production called *The Covered Wagon*, a touching love story with the epic quality of slowly and laboriously conquering a continent. Why not have a love story of

the vikings with the epic quality of fighting mutiny and storms to conquer an ocean. Jack Cunningham, recently a writer and associate producer at Paramount, wrote *The Covered Wagon*, so we engaged him to write *The Viking*. We spent $325,000 on this production and got our full money's worth of experience in all departments. But also we got our money back. The late Irving Thalberg, who was always our friend and a believer in Technicolor, thought we had a lot of production for that amount of money, and bought it for Metro by reimbursing our cost to us.

There seemed to be two principal troubles with *The Viking*, both of which I suspected but without certainty. First, it came out among the very last silent pictures in 1929 and, second, whiskers. Leif Erickson, the viking hero, true to character, had a long, curling mustache, whereas American audiences prefer their lovers smooth-shaven. At times the whole screen seemed filled with viking whiskers. But the picture was a good color job and the first to be synchronized with music and sound effect.

But thus far we had only isolated feature productions. The building of color cameras on the scale they exist today, the building of laboratories of sufficient capacity that prints could be made cheaply enough to make color generally available could not be carried on in terms of an occasional picture.

We brought out two-color imbibition prints with silver sound track in 1928. The advantages in respect of focus, cupping, scratching, size of reel, and cost of manufacture were immediate. The gelatin on the Technicolor imbibition film is harder than on ordinary black and white, and through the years there is substantial evidence that the life of Technicolor imbibition prints is greater than that of ordinary black and white.

By early 1929 all the important studios in Hollywood had become thoroughly sound conscious. This was a great help to us in introducing color. Prior to that, studio executives were loath to permit any change whatsoever in their established method of photography and production. But with the adoption of sound, many radical changes became necessary. Technicolor was always confronted with objections that photographing in color required more light, different costumes, a knowledge of color composition, additional time, and one or the other of these points, plus the added forceful argument that it cost more money, made it difficult for us to get started. In my opinion the turning point came when we ourselves produced the series of

short subjects. By entering the field as a producer, by keeping very careful records of our time and money schedules, and by openly discussing with studio executives everything that we were doing as we went along, we dissipated most of the prevailing misinformation. Meanwhile our quality was improving; our costs were decreasing. Warner Bros. and Metro-Goldwyn-Mayer were regularly coming out with satisfactory short subjects in Technicolor, and two inserts were highly successful, namely, *Broadway Melody* and *Desert Song*. Paramount had produced a successful feature length picture in Technicolor, *Redskin*. The studios were beginning to be *color* conscious.

But it remained for Warner Bros. and its affiliated company, First National, to take the first step on a *large* scale. Mr. J. L. Warner, with foresight and courage, signed up with us for a series of more than twenty features. These included *On with the Show*, the first all-talking all Technicolor feature picture, and *Gold Diggers of Broadway*, which has grossed over $3,500,000 and which still ranks high among the all-time outstanding box-office attractions. The Technicolor mechanical service of providing and maintaining cameras in good working order and of delivering rush prints on time was well established. Two more subtle departments of service, namely, helping producers' cameramen to learn how to light and operate to advantage in Technicolor, and consulting and advising in matters of color control, were being demanded. Coöperation under the head of color control was ranging all the way from deciding the details of the color composition of sets, choice of materials and costumes, to the broad planning and preparation of a picture by wiring a color score after the manner in which the musical score is written.

As evidence of the increased color-mindedness throughout the industry, Technicolor had contracts for the ten months beginning March, 1929, covering the photography and delivery of prints of the footage equivalent of approximately seventeeen feature length productions. This required a doubling of the Hollywood capacity which was accomplished in August, 1929. For the year 1930 Technicolor had closed contracts for thirty-six feature-length productions which would call for some 12,000,000 linear feet of negative to be sensitized, photographed and developed during that year in the Hollywood plant, and a print capacity of approximately 60,000,000 feet.

During this boom period of 1929 and 1930, more work was undertaken than could be handled satisfactorily. The producers pressed us to the degree that cameras operated day and night. Laboratory

crews worked three eight-hour shifts. Hundreds of new men were hastily trained to do work which properly required years of training. Many pictures were made which I counselled against, and all in the face of the fact that to book a picture in our crowded schedules called for a deposit of $25,000. At one time we had $1,600,000 of such cash payments.

Among the features photographed and released during this period were: *Bride of the Regiment*, Vivienne Segal (First National); *Bright Lights*, Dorothy Mackail (First National); *Doctor X*, Lionel Atwill and Fay Wray (Warner Bros.); *Fanny Foley Herself*, Edna May Oliver (RKO); *Fifty Million Frenchmen*, all-star cast (Warner Bros.); *Follow Thru*, Charles "Buddy" Rogers and Nancy Carroll (Paramount); *Gold Diggers of Broadway*, all-star cast (Warner Bros.); *Golden Dawn* (Warner Bros.); *Hold Everything*, Winnie Lightner, Georges Carpentier, and Joe E. Brown (Warner Bros.); *King of Jazz*, Paul Whiteman (Universal); *Kiss Me Again* (First National); *Life of the Party* (Warner Bros.); *Mamba* (Tiffany Productions); *Manhattan Parade* (Warner Bros.); *On with the Show*, all-star cast (Warner Bros.); *Runaround* (RKO); *Show of Shows* (Warner Bros.); *Song of the West*, John Boles and Vivienne Segal (Warner Bros.); *Song of the Flame*, Bernice Clair and Alexander Gray (First National); *Sweet Kitty Bellairs*, Claudia Dell and Perry Askam (Warner Bros.); *The Rogue Song*, Lawrence Tibbett and Catherine Dale Owen (Metro-Goldwyn-Mayer); *Sally*, Marilyn Miller (First National); *The Toast of the Legion*, Bernice Clair, Walter Pidgeon, and Edward Everett Horton (First National); *The Vagabond King*, Dennis King, Jeanette MacDonald (Paramount); *Under a Texas Moon*, Frank Fay, Noah Beery, Myrna Loy, and Armida (Warner Bros.); *Viennese Nights*, all-star cast (Warner Bros.); *Wax Museum*, Lionel Atwill (Warner Bros.); *Woman Hungry*, Sydney Blackmer and Lila Lee (First National); *Whoopee*, Eddie Cantor (Samuel Goldwyn and Florenz Ziegfeld).

In Warner's *Wax Museum* and Goldwyn's *Whoopee* the Technicolor two-component process may have reached the ultimate that is possible with two components.

By reason of the fact in Technicolor of complete separation of the sound-track technic from the picture technic, the necessity (as in black-and-white procedure) of compromise between the sound and picture quality is avoided and relatively better sound-track should result. The first to take advantage of this was Ted Reed who was in

charge of Mr. Goldwyn's sound department during the production of *Whoopee*. When that picture was shown in Hollywood the sound quality elicited much favorable comment and discussion among producers and technicians.

My greatest anxiety at the time was that there might be thrust upon the public productions which would be very crude in color composition and unfaithful in color reproduction. Our own color control department was doing everything possible to consult with and advise directors, authors, art directors, wardrobe heads, paint departments, and others in the studio, and this department was being expanded as fast as practicable. But there was more involved than questions of composition and design. There were the limitations of the process. As early as May 29, 1929, I reported to our directors: "The fact that we have signed this large volume of business on the basis of our present two-color process has not altered, in my opinion, the fact that the quality of this two-color output is not sufficiently good to meet with universal approval, and hence cannot be regarded as ultimate. I feel confident that the short-comings of our two-color process will be aided by the fact that they are combined with voice, and particularly by the fact that the work includes so many girl and music type productions like *Sally* with Marilyn Miller, and *Paris* with Irene Bordoni. Also this combination will offer a very considerable novelty angle for a time which is always important in the amusement world. Gradually, however, I believe the public will come to realize that these two-color pictures do not represent an ultimate natural color process. Consequently I feel urgently that our drive to put our process on a three-color basis as soon as possible should not in the least be abated because of our success in getting business on the two-color basis. This three-color work is moving ahead and involves a very considerable research department in Hollywood under the direction of Mr. J. A. Ball."

This premature rush to color was doomed to failure if for no other reason because the Technicolor process was then a two-color process. In the last analysis we are creating and selling entertainment. The play is the thing. You cannot make a poor story good by sound, by color, or by any other device or embellishment. But you can make a good story better. Broadway has a terrible struggle each season to find good stories or plays for a dozen successes. Hollywood is trying to find over five hundred. They don't exist. The industry

needs all the help it can get, all the showmanship it can summon—it needed sound; it needs color.

But color must be good enough and cheap enough. The old two-component Technicolor was neither—hence it failed, but it was a necessary step to present-day Technicolor.

During the rush to color, Technicolor had not only its own shortcomings to contend with, but also a surfeit of poor stories that were to be saved by color, and a monotony of musicals more or less on the same formula. An injustice was no doubt done Technicolor by causing it thus to be identified so largely with musical and period productions. I counselled at the time that producers were no doubt losing an opportunity in not taking advantage of the fact that color can be used to intensify dramatic effect and bring out the best points of personalities, advantages which have been later used with striking effectiveness.

During the years 1929 and 1930 Technicolor appropriated over $3,000,000 for plants, equipment, and research work, which increased its plant capacity from one million to six million feet of two-component prints a month. At the same time that it had been building those plants and training personnel to operate them, it had been filling its orders. Such conditions were not conducive to the highest quality product, even if the orders had been normal. The fact that this rush was largely forced upon Technicolor by the producers wouldn't help in the slightest degree with the exhibitor or the audience, even if they knew of it. And executives who were glad to try to work it out with us gradually over a period of time, were suddenly confronted with the necessity for drastic curtailment of their own budgets because of a sharp drop in motion picture theater attendance. At the peak of the rush Technicolor had twelve hundred men employed with a payroll of approximately $250,000 per month, whereas by the middle of 1931 these had dropped to two hundred thirty men and approximately $70,000. In the middle of 1931 picture production in Hollywood was at an extremely low ebb and the last week in July is said to have been the worst week for theater receipts in fifteen years.

During 1931 the base price of Technicolor prints was reduced from $8^3/_4$ to 7 cents per foot.

But Technicolor had persisted in its research and development work so that by May, 1932, it had completed the building of its first three-component camera and had one unit of its plant equipped to

handle a moderate amount of three-color printing. The difference between this three-component process and the previous two-component process was truly extraordinary. Not only was the accuracy of tone and color reproduction greatly improved, but definition was markedly better.

However, we could not offer the three-component product to one customer without offering it to all, which required many more cameras, and the conversion of much of our plant. To allow time for this and to prove the process beyond any doubt, we sought first to try it out in the cartoon field. But no cartoonist would have it. We were told cartoons were good enough in black and white, and that of all departments of production, cartoons could least afford the added expense. Finally Walt Disney tried it as an experiment on one of his "Silly Symphonies." This first attempt was the delightful *Flowers and Trees*, following which Disney contracted for a series. For Christmas 1932 came *Santa's Work Shop*, the following Easter, *Funny Bunnies;* in May, 1933, came *Three Little Pigs*, which made screen history, and in March, 1934, *Big Bad Wolf*. I needn't relate the story of Disney's extraordinary success with Technicolor. The "Silly Symphonies" in Technicolor surpassed the "Mickey Mouses" in black and white, and then both Mickies and Sillies adopted Technicolor.

Both the Disney Company and Technicolor were rather undersized at birth and in recent years both have grown rapidly in importance. A frequent conversation has been as to which helped the other most. Much like the conversation between two Irishmen after a considerable session at the bar: "Yer know, Clancy, when I was born I weighed only five pounds." "Yer did, and did yer live?" "Did I live? Yer ought to see me now."

What Technicolor needed was someone to prove for regular productions, whether short subjects or features, what Disney had proved for cartoons. But the producers asked: "How much more will it cost to produce a feature in three-component Technicolor than in black and white?" This question is always with us and it seems to me the answer must be divided into two parts; the added cost of prints, negative raw stock, rushes, and lighting can be numerically calculated and requires little discussion. But then there are the less tangible elements about which there is much discussion. I have said to producers and directors on many occasions: "You have all seen Disney's *Funny Bunnies;* you remember the huge rainbow

circling across the screen to the ground and you remember the Funny Bunnies drawing the color of the rainbow into their paint pails and splashing the Easter eggs. You all admit that it was marvelous entertainment. Now I will ask you how much more did it cost Mr. Disney to produce that entertainment in color than it would have in black and white?" The answer is, of course, that it could not be done at any cost in black and white, and I think that points to the general answer. A similar analogy can be drawn with respect to some part of almost any recent Technicolor feature.

If a script has been conceived, planned, and written for black and white, it should not be done at all in color. The story should be chosen and the scenario written with color in mind from the start, so that by its use effects are obtained, moods created, beauty and personalities emphasized, and the drama enhanced. Color should flow from sequence to sequence, supporting and giving impulse to the drama, becoming an integral part of it, and not something superadded. The production cost question should be, what is the additional cost for color per unit of entertainment and not per foot of negative. The answer is that it needn't necessarily cost any more.

In 1932 we marked our base print price down from 7 cents to $5^1/_2$ cents a foot.

Early in 1933 Mr. Merian C. Cooper and Mr. John Hay Whitney began to show a practical interest in Technicolor. After thorough investigation of the Technicolor situation by Mr. Whitney and his associates, and as a result of many conferences, a contract was signed between Technicolor and Pioneer Pictures, Inc., on May 18, 1933, which provided for the production of eight pictures, superfeature in character and especially featuring color. There were some conditional clauses, among others a provision for extensive preliminary tests. Certain doubts remained in the minds of Whitney and his associates as to the performance of our three-component process under certain conditions. Would the process reproduce the various shades of green in woodland and jungle? For one story they were considering a lead with very dark coloring and black hair. Would she photograph satisfactorily against light backgrounds? For another story they thought of placing a decided blonde in the leading part; how would she photograph against various backgrounds? What about make-up? What about the visibility of extremely small figures in the distance? An exhaustive sets of tests were made with results satisfactory to Mr. Whitney and Mr. Cooper.

Then began the hunt for the first story to be produced. At one time Whitney told me they had given consideration to no less than two hundred stories.

While Mr. Whitney was searching, Pioneer Pictures made a very practical and complete test of the process by producing the picture *La Cucaracha.* This short subject met with tremendous success.

La Cucaracha, together with "Silly Symphonies," caused a tremendous interest in three-component Technicolor. The industry was now waiting to see what the first Whitney feature production would be like. Meantime Technicolor business was improving. Positive film shipments for the first six months of 1933 were double what they were for the first six months of 1932. Appropriation was made to increase the number of cameras under construction from three to seven.

The first test of the three-component process on a very large set was for Twentieth Century Fox on the closing sequence of *The House of Rothschild.*

Since *Whoopee* in 1930 Mr. Goldwyn and I had talked regularly each year about another picture in Technicolor, so that on one occasion Eddie Cantor asked me if I were coming for my annual ritual. This time it was the closing sequence in his Cantor picture, *Kid Millions,* which was another important early three-component insert.

No account of Technicolor adventures in the realm of producers would be complete without affectionate mention of Mr. Andrew J. Callaghan. He was a Vice-President of the company, active in sales and studio contacts through our most troublous times. He was Hollywood's most popular man—loved by all—and has been tremendously missed by everybody in Technicolor since his death in 1934.

Mr. Whitney and his Pioneer Pictures associates finally settled on *Becky Sharp* as their first production of the series of eight. *Becky* was a champion for hard luck. The original director, Lowell Sherman, was taken ill and died during the period of photographing. He was succeeded by Reuben Mamoulian. Unusual difficulty was encountered in the sound recording so that Mr. Whitney found himself in the ironically anomalous position of having produced the first three-component Technicolor feature, of having surmounted all the hazards of color, yet being in difficulty with an aspect of the work which he had naturally taken for granted.

During the 1935–36 season we were manufacturing in the neighborhood of $2^3/_4$ million feet of prints a month, which included a larger volume of Warner Bros. short subjects than ever before and about forty per cent of all Metro-Goldwyn-Mayer short subjects.

A very interesting and important adventure in the history of Technicolor development was the organization of a British affiliate, Technicolor, Ltd., which I organized as a subsidiary of Technicolor Motion Picture Corp. and later developed in association with Sir Adrian Baillie, Mr. Alexander Korda, and The Prudential Assurance Company, Ltd.

The first Technicolor feature picture photographed in England was *Wings of the Morning*, a race-track story which has had very successful distribution throughout the world. This production was produced before the London laboratory was built, and was serviced from Hollywood. In 1936 the British laboratory was built at West Drayton, just outside of London where it is now regularly operating to service British made productions and prints of American made productions for distribution in the United Kingdom. Mr. Alexander Korda has been outspoken in his enthusiasm for color, as evidenced by a series of pictures which he has produced, including the current release *Drums*. He is now planning an all-Technicolor series of pictures, of which the first is *The Four Feathers*, at present being photographed in the Sudan.

Since *Becky Sharp* there have been produced at Hollywood and in London a large number of important feature productions in Technicolor, including: *Adventures of Robinhood*, Errol Flyn, Olivia de Havilland (Warner Bros.); *A Star Is Born*, Janet Gaynor and Fredric March (Selznick International Pictures); *Drums*, Valerie Hobson, Sabu, Raymond Masey (London Films Productions); *Ebb Tide*, Ray Milland, Frances Farmer (Paramount); *Garden of Allah*, Marlene Dietrich, Charles Boyer, Basil Rathbone, Joseph Schildkraut (Pioneer Pictures); *God's Country and the Woman*, George Brent, Beverly Roberts (Warner Bros.); *Gold Is Where You Find It*, George Brent, Olivia de Havilland (Warner Bros.); *Goldwyn's Follies*, all-star cast (Samuel Goldwyn Pictures, Inc.); *Her Jungle Love*, Dorothy Lamour, Ray Milland (Paramount); *Men with Wings*, Ray Milland, Louise Campbell, Fred MacMurray (Paramount); *Nothing Sacred*, Carole Lombard, Fredric March (Selznick International Pictures); *Ramona*, Loretta Young, Don Ameche (Twentieth Century Fox Productions); *Sixty Glorious Years*, Anna Neagle, Anton

Walbrook (Herbert Wilcox); *Snow White and the Seven Dwarfs*, Walt Disney (RKO Pictures, Inc.); *Trail of the Lonesome Pine*, Sylvia Sidney, Fred MacMurray, Henry Fonda (Walter Wanger Productions); *Tom Sawyer*, Tommy Kelly, Anne Gillis (Selznick International Pictures); *Valley of the Giants*, Claire Trevor, Wayne Morris (Warner Bros.); *Vogues of 1938*, Joan Bennett, Warner Baxter (Walter Wanger Productions).

Generally speaking, these pictures have been extraordinarily well received, some of them having broken attendance records in many parts of the world. Thus Technicolor has met the second great rush into color with steadily improving quality of its product and a broadening range of service. It is the purpose of Technicolor, during the time that prints of any picture are being manufactured in its plant, to hold the laboratory open for and at the disposal of the customer as if it were his own. His representative may inspect each of his prints and any changes suggested will be undertaken if practicable. To do this he simply moves into the inspection room where each print before shipment is compared by simultaneous projection with a standard print approved by the customer for the purpose.

William Wellman who has directed more three-component Technicolor pictures than any other individual, all of them successes, namely, *A Star Is Born*, *Nothing Sacred*, and *Men with Wings*, has said repeatedly of Technicolor photography that he takes it in his stride, at substantially the same number of setups per day as black and white. It is noteworthy that most of the camera work is now done by cameramen in the direct employ of the studios.

Broadly considered, this recent array of feature pictures is of such a late date that it is too early to render a verdict based upon any sort of generalization with respect to them.

Looking ahead, Technicolor has contracts for about forty feature-length productions spread among most of the outstanding producers, constituting a very substantial volume of business. Among these there are now either being photographed or in preparation the following: *Dodge City*, Errol Flynn, Olivia de Havilland (Warner Bros.); *Gone with the Wind*, Clark Gable (Selznick International Pictures); *Heart of the North*, Dick Foran, Gloria Dickson (Warner Bros.); *Jesse James*, Tyrone Power, Henry Fonda, Nancy Kelly (Twentieth Century Fox); *Kentucky*, Loretta Young, Richard Greene, Walter Brennan (Twentieth Century Fox); *Little Princess*, Shirley Temple, Richard Greene, Anita Louise (Twentieth Century Fox); *Northwest*

Passage, Robert Taylor, Spencer Tracy (Loew's, Inc.); *Sweethearts,* Jeannette MacDonald, Nelson Eddy, Frank Morgan, Ray Bolger (Loew's, Inc.); *The Light That Failed,* Ray Milland (Paramount); *The Mikado,* all-star (G. & S. Productions, Ltd.); *The Thief of Bagdad* (London Films Productions); *The Wizard of Oz,* Judy Garland, Jack Haley, Bert Lahr, Ray Bolger (Loew's, Inc.); and a second feature-length production is being prepared by Walt Disney Enterprises, Inc.

To meet this growing volume of business Technicolor many months ago appropriated some $1,500,000 to increase the number of its cameras and to double its plant capacity. This expansion program is now well on its way to completion.

I have thus passed over rapidly the matter of eighteen pictures to be produced in Technicolor during the last part of this year and the first six months of next year, although they will probably represent an investment of some fifteen million dollars.

The foreign situation is becoming increasingly difficult. Sales to Germany, Spain, Japan, and China have practically ceased, and in many other foreign countries they are below normal. The Italian Government controls the entire distribution of films in Italy, which probably means that everything possible will be done to distribute Italian-made pictures at the expense of English and American-made pictures. To cope with the various regulations of censorship, the various languages requiring either superimposed titles or dubbing with new sound-track, has for years been difficult enough, but with the more recent quota laws, import duties, exchange difficulties, and especially in the face of the impossibility of getting money out of several foreign countries, to continue in the motion picture business there means adventures in other businesses, possibly including banking and politics. The establishment of Technicolor laboratories at various points over the world is a practical necessity and despite all these difficulties definite progress is being made.

About a year ago Technicolor established a department to contact exhibitors directly. Its representatives travel over the country to call upon exchange managers, theater managers, and projectionists. The purpose has been to study projection and screen conditions at the theater; to advise how to get the best results with Technicolor prints, to listen to complaints and establish good will, and particularly to obtain projectionist, manager, and audience reactions to productions in Technicolor. The results have been most gratifying; we

have found that the public reaction to Technicolor pictures is extremely favorable and that exhibitors throughout the country are realizing more and more that Technicolor has great box-office value.

In the letter from Dr. Goldsmith, suggesting for himself and Mr. Crabtree, that I write this paper, he said, "I believe it would be of particular interest to the engineers and the industry if you cared to indicate how you happened to cling so tenaciously to these developments through the 'dark ages' when color motion pictures were not so well appreciated." All I have said points to the answer; it was marvelously interesting; it was great fun; we couldn't let anybody down, neither customers, employees, stockholders, nor directors. But there was something else too; there was always something just ahead, a plan for tomorrow, something exciting to be finished—yes, and something more to be finished after that; and I am willing to predict that it won't be finished for many years yet. The type of film which will be standard for natural color pictures ten years hence may not yet have emerged. I predict that within two years Technicolor will have done away with special cameras and be regularly employing single strips of negative through any standard motion picture camera and that within two months for special purposes and within six months for more general purposes it will be offering to its customers a negative for use in its present cameras with from three to four times the speed of its present negative. That's why we cling so tenaciously; there's always something ahead; there always will be; our pride is enlisted; it's our job.

DISCUSSION

MR. CRABTREE: I have been greatly impressed by the way in which color develops the loveliness of the ladies, especially the blondes and the redheads. Are the producers sold on the fact, and do they make screen tests of potential stars in both color and black and white?

DR. KALMUS: The program of testing is always with us. There has been no end of tests, both in black and white and in color, for comparative purposes. Relatively few are being made now; many producers think they are not necessary.

MR. CRABTREE: I have been wondering whether the usual methods of inserting backgrounds are being used with Technicolor. Were there very many background shots in *Men with Wings?*

DR. KALMUS: We do projection background work regularly.

MR. CRABTREE: Is it as flexible as with black and white?

DR. KALMUS: Not quite, but sufficiently flexible to be very practicable.

MR. WOLF: I understand Technicolor will be available in a single film for use in standard cameras. Will the processing be difficult or will it be as simple as with black and white?

DR. KALMUS: That is getting into a realm I am avoiding for the present. However, I think it will be some time before the processing will be as simple as black-and-white, if ever. The program as we have it outlined will be simple and practicable as compared with the programs we have been through before.

MR. KELLOGG: When you have a two-color system, do you leave some silver in the film in order to get some black in addition to what you get from the dyes?

DR. KALMUS: The two-component system was strictly two-component. The present system is really four-component—the three components ordinarily thought of as the color components, and black.

MR. THOMAS: Have you obtained any data of value, from the projection standpoint, from the questionnaires sent out with the prints of *Goldwyn Follies?*

MR. RACKETT: We have received valuable information from the projectionists' comments on the cards sent to theaters in advance of the showing of Technicolor pictures.

The comments may be divided into two classes: first, those referring to the physical condition of the film, which have occasioned our making minor changes in the visibility of instruction titles and changeover cue marks; the second, relating to the density and color values of prints, which are a little more difficult to classify as they have to be interpreted in connection with data from our field division relating to projection equipment.

Most theaters are equipped with high-intensity arcs which produce a screen image that is slightly bluish. Technicolor prints are balanced to yield a neutral image on such a screen.

Small projection units equipped with Mazda light produce a screen image that is slightly orange. When a print balanced for a high-intensity arc is projected by a Mazda light the screen result will be slightly orange.

When we are establishing the density and color balance of a feature picture, we make a series of prints and usually arrange to view these with the producer of the picture in a number of first-run theaters, as far as time permits. We then compare a number of prints in a room where we can project simultaneously on matched screens as many as six prints of the same reel. We get a comparison of such fineness that we have not been able to find quantitative methods of measuring the differences.

All the data, including the important and welcome comments of the projectionists on the print comment cards attached to the print suggestion booklets, are very helpful in establishing the final results.

MR. GRIFFIN: How quickly is the rush print available in the three-component process after the negatives leave the camera?

DR. KALMUS: Regular twenty-four hour service.

A METHOD FOR DETERMINING THE SCANNING LOSS IN SOUND OPTICAL SYSTEMS*

E. D. COOK** AND V. C. HALL†

Summary.—*The usual methods of evaluating the frequency characteristic of sound records have been satisfactory for the determination of the required correction for overall losses. However, the losses due to aperture and optical effects are not known with sufficient precision to permit an inferior limit to be assigned to film loss only.*

The method described was chosen in connection with a high-fidelity development and consists of comparing direct measurements made on images formed by contact printing a geometrically shaped test-object on the film with measurements of frequency records made using the recorder optical system. While the results obtained cannot be applied generally as yet, due to the difficulty of correcting for variations in slit illumination, and for different gammas, the method is capable of segregating film loss from other losses for the specific conditions under which the test is conducted.

In the early development of the high-fidelity system, considerable compensation was employed in recording to overcome the effect of high-frequency losses. Technical disagreements over the amount of correction required were encountered almost at once. Part of the difficulty was due to the variations in film characteristics obtained by different laboratories. Measurements of film losses were reported that disagreed among themselves. The need for precise methods for the measurement of these losses was evident and this was not dispelled even by the eventual agreement on overall recording losses.

Since artistic achievements are dependent in part, at least, on technical improvements, it was desirable to establish, if possible, the inferior limit for film loss, for, as more knowledge became available concerning these losses, it seemed logical that means for reducing high-frequency compensation might be devised. This would release for useful recording a portion of the amplitude range otherwise employed merely to overcome losses.

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** General Electric Co., Schenectady, N. Y., formerly RCA Manufacturing Co., Camden, N. J.

† Eastman Kodak Co., Rochester, N. Y.

For these reasons, it was felt desirable to examine other methods of determining the frequency loss due to the film alone, and that these methods should be as divorced as possible from optical systems and apertures even though the test conditions were somewhat different from those of actual recording. It seemed probable at that time that much remained to be said concerning the effect of the optical system on losses ascribed to the emulsion. A method independent of the recording optical system would offer a useful means of experimentally determining the magnitude of the combined losses caused by the optical system. For want of a better designation, the combined losses due to the optical system will be called scanning losses.

Two general methods of steady-state analysis are available for film measurements: one is static, while the other is dynamic. As is implied, in the first method a sinusoidal exposure is made, usually on a small sample, and the result is analyzed by the methods of harmonic analysis. In the second method, sinusoidal recordings at various frequencies throughout the desired spectrum are made and the record, analyzed by a densitometer or from the output of a reproducer whose characteristics are known, is employed to give the desired information. Each method has advantages for certain problems and, similarly, each has its faults.

For example: In the dynamic method, aperture distortion and reduction of image contrast due to lens flare and other stray light in recording, are too imperfectly known to permit the correct portion of the total loss to be assigned to the film, while in the static method, it is essential to determine that no significant error is introduced into results intended for application to recording conditions by the failure to employ an equivalent exposure time; that is, the failure of the reciprocity law, or from failure to have the recording light preserve the same angles of incidence as are employed in direct recording when a recording mask is used to provide the wave-shape. This might introduce errors if the results were used in the determination of the overall losses for a system under usual operating conditions. In evaluating the film loss by the dynamic method, it would also be necessary to provide sufficient constancy of film motion in recording as well as in reproducing to insure accuracy and uniformity in the result. The oscillator wave-shape would have to be adequately free from harmonics; amplifiers, galvanometers, *etc.*, should have linear response, while optical system images should have uniform illumina-

tion and the influence of such effects as chromatic and spherical aberrations would have to be known.

In the static method, there is a choice of analyzing separate samples of different wavelengths or of employing a complex wave-shape from which the amplitudes of the various frequencies are determined by the method of harmonic analysis. In the first alternative, the number of samples needed for analysis, in order to insure the accuracy and uniformity of the result, would be quite large; whereas, in the latter, measurement errors due to any increased steepness of wave-front resulting from the superposed frequencies would have to be guarded against. Likewise another possible measurement error arises from the necessity of taking differences between a measured quantity and the applied value of that frequency if the amplitude of the latter is allowed to become small. The general agreement of a reasonable number of results in either method would be required as a safeguard from accidental error. In spite of the conditions for reciprocity and collimation of exposure, the static method is especially attractive for film characteristics, since all aperture and optical system losses can be practically eliminated. It is evident that by proper comparison between the two methods, scanning losses may be determined. The results of some of the preliminary work with the static method will be given. These are not intended for use in an accurate determination of film or scanning losses, but are given merely to illustrate what information is obtained by this method. Further work must be done to define accurately the losses mentioned.

The tests were developed from the mathematical viewpoint rather than the one mentioned above. It is the property of a linear system having constant coefficients, that the "steady-state" behavior is indicated by its "transient response." However, in the mathematical case, a second "transient" at a later "time" coördinate would not affect the "response" at a previous "time," whereas, in film work, the "time" coördinate is transformed into a "distance" coördinate by the film motion and a sort of "adjacency" effect, which causes the "transient" to extend in both directions, is known to exist. Therefore, it was concluded that the simple expedient of exposing a film to the correct degree on one side of a straight-edged mask (which prevented exposure everywhere else) and analyzing the growth of density at the transition, should be replaced by some other process, preferably a periodic one, in which wave-shape changes would include the "adjacency" effect and reveal losses in frequency response. Such an

exposing process is found in the stationary exposure of a square wave-shape. Composed, as it is, strictly of the odd harmonics, it is impossible to change its square wave-form by any operator which raises it to a power, integral or fractional, or by adding or subtracting various combinations of this operation. This property is especially useful in electrical circuits, since even a rectifier does not affect the inherent "squareness" of the resultant wave; that property can only be affected by the variation of frequency selectivity of the circuit.

For practical work, a wave of moderate frequency would preserve much of its "squareness" if the transmission were constant only over the essential range of audio frequencies. The loss of amplitude of odd harmonics during transmission results in the creation of even harmonics only in the presence of non-linearity; *i. e.*, if the harmonics modulate one another. It has been a fundamental assumption that the film is sufficiently "linear" to permit superposition of stimuli without cross-product or modulation terms. The correctness of this assumption was tested to a reasonable degree of accuracy before these experiments were begun. The results found by Baker and Robinson[1] for variable-amplitude recording also show the assumption well warranted, at least to the order of approximately one per cent over the density range found satisfactory for commercial sound records. It was concluded, therefore, that any departure from "squareness" in the resultant wave-shape of records falling in this density range could be safely attributed to change of amplitude of harmonics, viewing the whole process as a stimulus acting through an operating function to produce the resultant wave of density. It is interesting to observe that a 100-per cent modulated square-wave record made by amplitude recording would be indistinguishable from one made by density recording.

The physical reasoning applying to images made under conditions of minimum distortion is apparently much simpler. If the system is sufficiently linear, it is merely necessary to employ an adequate number of frequencies of known amplitudes simultaneously. Then, if cross-product terms do not exist, it is convenient to choose only the odd harmonics having assurance that the amplitude of any harmonic has not been altered to a significant degree by the interaction of any two different frequencies through cross-product terms of any order.

The amplitude of the harmonics in a square wave of height A may be obtained from equation *1*.

$$y = \frac{4A}{\pi} \sum_{n=1}^{n=\infty} \frac{1}{n} \sin nwt \qquad (1)$$

where $n = 1, 3, 5,$ *etc.* . . .

This particular wave-shape has mechanical advantages in constructing the test-object to be used as a mask. This offsets to a large degree the difficulty due to the decreasing amplitude of the higher order harmonics.

In common with all experimental work, these results are valid for conditions of the tests. The difficulty of exposing the sample film under conditions comparable to those used in the dynamic method resulted in the choice of the conditions employed for these tests. Therefore, the film loss indicated may not be applied generally except to these conditions. However, consistent differences between this method and the measurements made on frequency records using usual recording equipment may, for comparable conditions, be regarded as a scanning loss. It would be incorrect to ascribe such extra losses to the film since they would be the result of circumstances not common to the two methods of test, and if sufficient care has been used in regard to unnecessary faults, such as lack of sufficient speed constancy, *etc.*, in the dynamic method, these circumstances are limited to the optical systems. It may be entirely correct to say that present-day technic knows no way to improve scanning conditions and therefore obtain lower overall losses, but it is not logically correct to assign the excess losses to the film. For example, assuming that lens flare has been reduced to the absolute minimum that modern skill can attain, some flare still exists and causes a reduction in contrast in the optical image. Methods which do not involve an optical system should therefore show lower losses under conditions otherwise equivalent to methods which do employ optical systems. The differences in these losses are logically chargeable as scanning losses, this being the only difference. In fact, if two records are, in general, to have the same frequency response, special care would have to be exercised to avoid all serious optical differences, since exposing stimuli of the same total amount but varying durations or varying degrees of collimation of light, could hardly be expected to produce films having the same frequency response. The effect of a reduction of contrast between an object and its image due to an optical system has been mentioned, but it must be noted that any change in final contrast, whether due to the characteristics of the optical system or those of

the film, affects the scanning losses obtained. For this reason, the scanning losses obtained under one set of conditions should not be applied, without evidence of their validity, to an entirely different set of conditions. Thus, a film of high contrast, which would tend to minimize the effect of lens flare, would produce lower scanning losses than would be the case for a film of lower contrast where the density developed due to exposure to low level illumination, such as lens flare, would be greater.

While the ultimate or complete segregation of the various losses in the frequency-response graph would require further and extended research, nevertheless the results obtained so far by the square-wave method of analysis show how remarkably faithful present-day film can reproduce an event, such as the recording of high-frequency sine waves, if proper conditions are provided.

The square-wave test-objects were prepared by the Bausch & Lomb Optical Co. to have equivalent wavelengths corresponding to 100, 1000, and 5000 cycles per second, and were accurately of the same amplitude. These were analyzed and found to possess the distribution of harmonics shown in Table I. The deviations from the theoretical values required by equation *1* are seen to be small.

TABLE I

Freq.	Percentage Amplitude of Harmonic									
	1	2	3	4	5	6	7	8	9	10
100	100 0	0.8	33.1	0.2	19.5	0.5	14.0	0.5	10.8	0.4
1000	100.0	2.7	32.8	3.0	19.2	3.0	14.1	3.0	10.1	2.8
5000	100.0	6.1	32.4	6.2	17.8	6.2*	11.1*	5.8*	7.5*	7.2*

* Corrected for the aperture and recording galvanometer losses of the microdensitometer.

The test-objects themselves consisted of three blocks of glass 10 mm. by 20 mm. by 7 mm. thick with the square-wave forms ruled on a silvered surface. Three complete cycles were ruled in each test-object, the amplitudes and edges being held to tolerances of approximately ± 0.001 mm. Small pinholes, lack of squareness in the corners, and nicks in the ruled edge led to a total inaccuracy of somewhat more than this value, but, since the wavelength of the 5000-cycle unit was 0.092 mm., it can be seen that the limit of error in the ninth harmonic ($\lambda = 0.010$ mm.) would be of the order of 10 per cent, while at longer wavelengths, the errors would be entirely negligible because of other variations. The appearance of the test-objects is

illustrated in Fig. 1, which is a print of the 1000-cycle test-object. At the magnification shown, a departure from straightness of the edges or lack of squareness at the corners sufficient to have appreciable effect at frequencies ten times the fundamental would be easily discernible.

The three test-objects were mounted in a frame arranged with a pressure-pad arrangement to hold 35-mm. film in close contact with the silvered surfaces. This made up a printing frame which was mounted about 3 feet from a lamp house equipped with a shutter. Sufficient neutral absorption was interposed to adjust the exposure to about 10 seconds for Eastman emulsion *1357*. While the exposures made in this way, of course, do not compare in time with sound recording exposures, no data on variations of image quality with intensity are available. It is probable, however, that no great change in the characteristics of an image of microscopic size would occur without some corresponding change in the macroscopic qualities, such as gamma and rate of development. Over the range of intensities encountered here, the primary change in film emulsion characteristics is that of sensitivity variation, so that no considerable change in image quality would be expected between the two sets of exposures, except that attributable to the difference in optical systems.

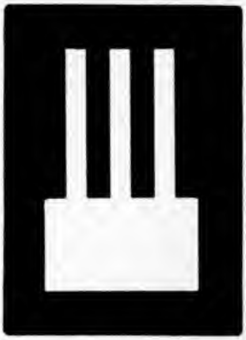
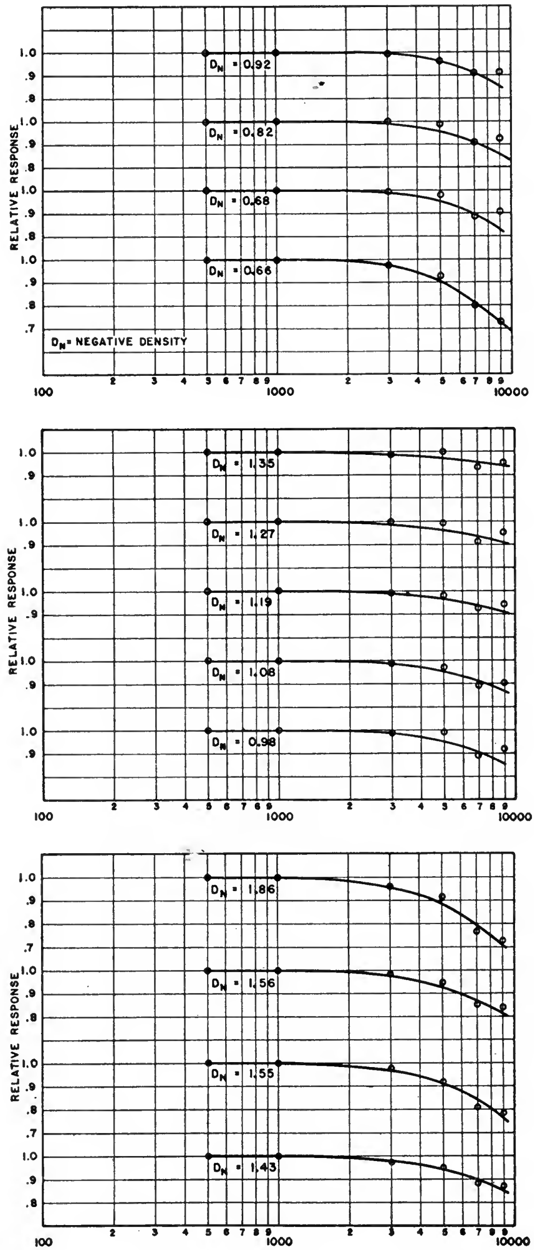


FIG. 1. Print of 1000-cycle per second silvered test-object.

FIG. 2. Microdensitometer trace of 1000-cycle square wave-form negative.



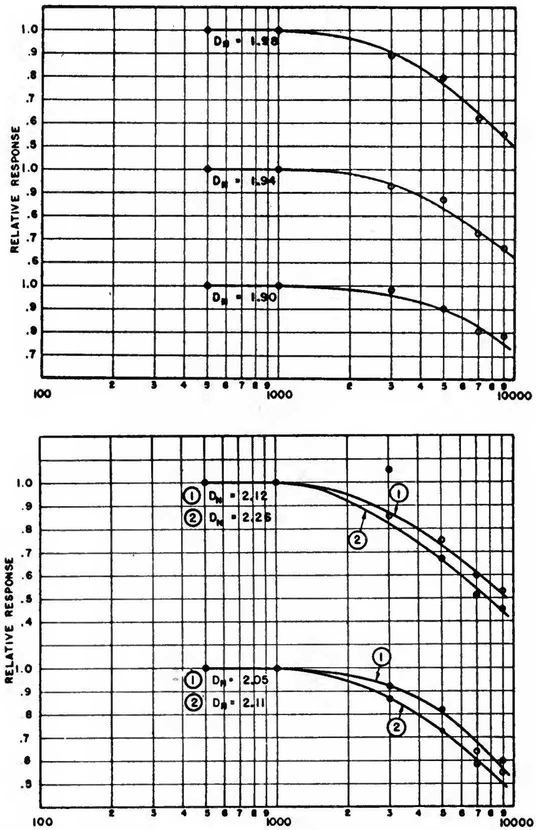
FIGS. 3–5. Relative response of negatives made by square-wave mask for various densities.

The exposures were made on 12-inch strips of 35-mm. film developed by machine, with sufficient agitation to insure even development.[2] Microphotometric traces of the images were made and enlarged to a wavelength of 40 cm. to enable analysis to be carried out on a Henrici type harmonic analyzer.[3,4] A comparison of the amplitude of any harmonic with the theoretical value given by equation *1* then indicates the loss due to the film under the experimental conditions under consideration. A correction was made in each case for the deviation of the test-object from the theoretically correct value, the final result being a frequency-response curve with an experimental point for each odd harmonic up to the ninth, since this is the highest harmonic it was possible to read. Since the data obtained from analysis of the records made with 1000-cycle per second fundamental amplitude are the most useful, only these values are presented. A print of the microdensitometer trace obtained from the image of the 1000-cycle test-object having a density of 1.08 is shown as Fig. 2. The small irregularities at the top and bottom of the wave are due to the fact that in ruling the test-objects the engraving tool cuts up to the line on each stroke, thus inevitably leaving a somewhat jagged line when magnified to this extent. The slope of the nearly vertical part of the line and the sharpness of the corners are the only factors influencing the value of harmonics up to the tenth, however, so these unevennesses cause no measurable error.

The negative test data for Eastman emulsion No. *1357* are shown as frequency-response graphs for a range of negative densities from 0.66 to 2.26 in Figs. 3–7. These curves have been corrected for the loss of the test-object. It is seen that the frequency-response does not show severe high-frequency losses even at quite low negative densities. High negative densities seem to produce more serious losses. This might have been expected but it is probably not so well recognized that any set of exposure conditions would result in the low losses shown at high frequencies, particularly for the best negative density conditions.

The square-wave analysis for this emulsion yields results which correspond to those of dynamic tests in regard to the range of negative densities which provide the best frequency response. That the range is broad is as might be expected; actually it varies from about 0.8 to 1.4 density with a maximum at about 1.25. However, the choice of recording density can not be made on the basis of frequency-response alone, since this need not correspond with maximum volume

minimum noise, or minimum distortion conditions for either negative or print. It has been shown that random hiss decreases with negative density,[5] hence a compromise must be made between the conditions for minimum loss and minimum noise. A choice of recording density of between 1.4 to 1.5 has been previously made for this emul-



FIGS. 6–7. Relative response of negatives made by square-wave mask for various densities.

sion for white-light exposures and it is seen that these conditions do not represent a serious compromise with conditions for minimum film losses.

A comparison between the negative losses as obtained from microdensitometer measurements of a recording made on a *PR-18* recorder

and a contact negative made from a square-wave mask on Eastman emulsion *1357* is shown in Fig. 8. The samples were developed to a gamma of 2.1 and had a density of 1.50 diffuse. Because of the failure of the law of reciprocity, it is probable that this does not exactly portray the recording scanning loss, but it seems reasonable that the values shown are not in error by more than 5 per cent.

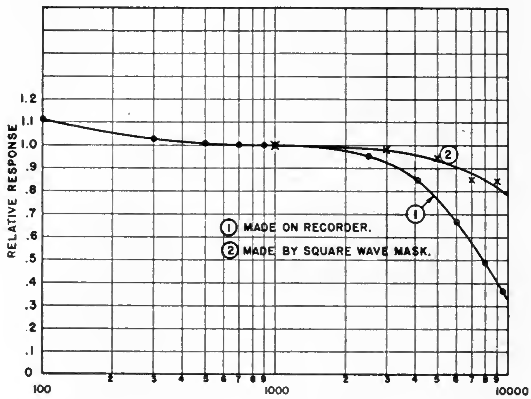
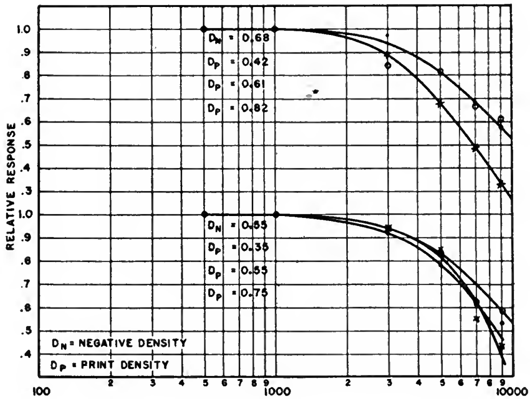
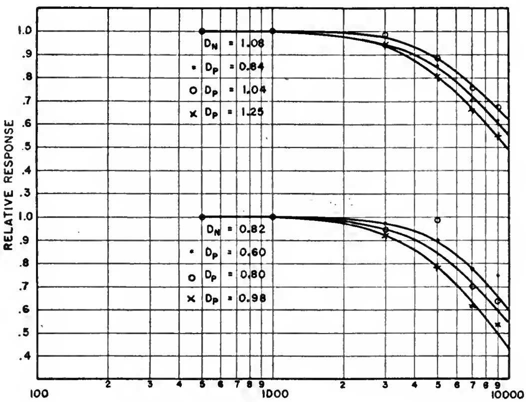


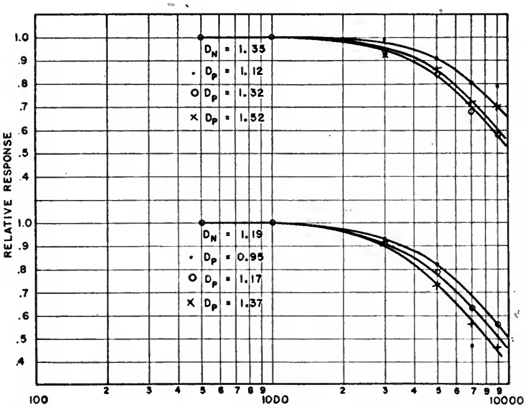
FIG. 8. Comparison of frequency response of negatives on Eastman emulsion *1357* for density 1.5, gamma 2.1.

The negatives of various densities obtained from the square-wave test-objects were contact printed onto Eastman positive film, type *1301*, and developed in *D-16* developer to a gamma of 2.0. These prints, which had densities ranging from 0.2 less than to 0.2 greater than the density of the negative, were similarly analyzed by the microdensitometer and the harmonic analyzer. The results are shown by the curves in Figs. 9–16. These curves have been corrected for the loss of the test-object. It is seen that in every case, for negative densities less than about 1.8, the loss of high-frequency response in the print exceeded that of the negative. In most cases, the response was less than the product of the negative percentage response by itself. The exceptions were all at the higher negative densities at which the prints showed a response approximately equal to that of the negative.

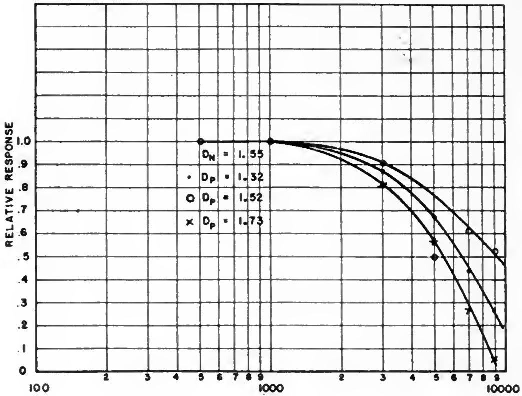
It is thought that this is evidence of the scattering of light by the negative with a consequent loss of contrast in the print. At the higher negative densities, the "filling-in" of the clear portion of the

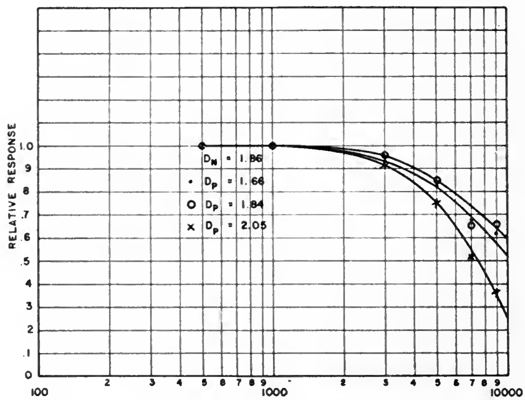


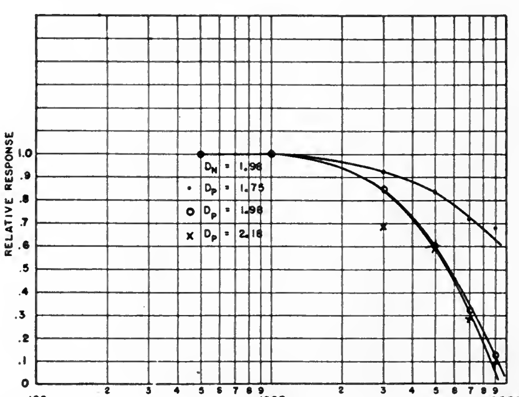




FIGS. 9–11. Relative response of print made from square-wave mask negative on emulsion *1301*.

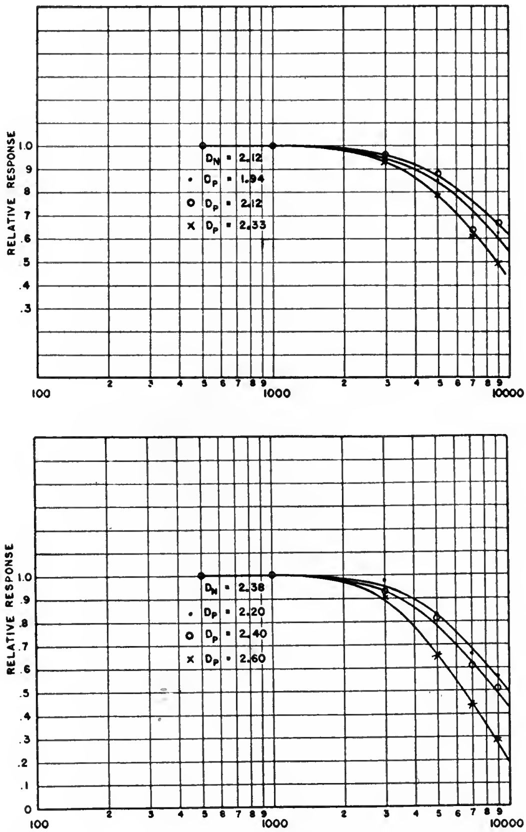






FIGS. 12–14. Relative response of print made from square-wave mask negative on emulsion *1301*.

negative was probably compensated in the print, resulting in no material increase in high-frequency losses. Since these densities are beyond the range for best general performance, the results are of lesser consequence in this work than those at the lower densities.



FIGS. 15–16. Relative response of print made from square-wave mask negative on emulsion *1301*.

It might seem that, because of the relatively high printing loss observed, the possible small film loss, which might be achieved in recording if scanning losses were reduced or entirely eliminated, would be of small consequence. This conclusion does not follow from the data shown, for an inferior limit of film loss for emulsion *1301* has not been given, and even if it were assumed that the difference between

the negative loss and print loss is all ascribable to the positive film, the use of a different type of negative emulsion might change the printing conditions for minimum distortion and cross-modulation products to a value of print density which would show considerably less loss ascribable to the positive film.

In Fig. 17, a comparison is shown between a contact print of density 1.50 and gamma 2.05 made on emulsion *1301* from a recorded negative of density 1.50 and gamma 2.05 on emulsion *1357* and a contact print of density 1.52 and gamma 2.0 made on emulsion *1301* from a square-wave negative of density 1.55 and gamma 2.2 made on emulsion *1357*. The losses in both cases have increased over the corresponding losses shown in Fig. 8 for the negative records, but,

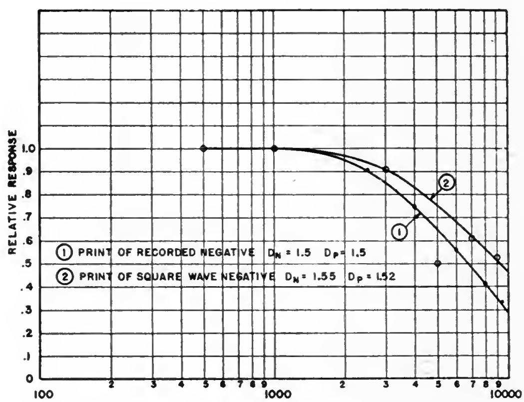


FIG. 17. Comparison of frequency response of prints made from recorded negative and square-wave negative.

while the printing loss for the sound record has an increased loss of 1.4 db., the square-wave negative has an increase of 4.4 db. Since, as stated above, no absolute measurements on *1301*-type film were made, the cause of this differential can not be determined.

CONCLUSION

A comparison of the results shown in the curves of Fig. 8 and Fig. 17 indicates that at 10,000 cps. there is a scanning loss due to the recorder optical system of 7.2 db. for records made under what are considered satisfactory white-light recording conditions for type *1357*

sound-recording negative, and 4.2 db. as the overall scanning loss when these negatives are printed onto type *1301* film.

The losses ascribable to the optical system are the result of light falling on the film outside the area defined by the slit image. The photographic effect of this extraneous light will depend, of course, on the contrast to which the film is developed, so a complete understanding of the way in which the image fails must await the analysis of data obtained under a wide variety of conditions.

Since the modulation loss at 10,000 cycles per second of *1357*-type sound-recording film may be as low as 1 to 2 db. under favorable exposure and development conditions, it is probable that the corresponding "static" loss for records made on recently introduced fine-grain high-contrast sound-recording emulsions will be as low as $^1/_2$ db. If this is found to be true, then the dynamic losses found on high-frequency sound records made under the best exposure and development conditions can be considered almost entirely as scanning losses, and practical experiments on sound-recording optical systems can be analyzed on the basis of negligible loss attributable to the film itself. Since part of the reduction in scanning loss of these emulsions is due to the higher gammas to which they are developed, thus reducing the photographic effect of extraneous light surrounding the slit image, a study of the relationship between development and scanning losses may make it possible to evaluate the effect of flare in the optical system more accurately.

In conclusion it is desired to acknowledge the sponsorship of Mr. M. C. Batsel of RCA Mfg. Co., whose interest in film and scanning losses stimulated the authors to devise and investigate the possibilities of this method.

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DISCUSSION

MR. CARLSON: As I understood the procedure for determining the final response, a scanning beam was projected on the film and the response measured through the film?

MR. COOK: In the square-wave test method?

MR. CARLSON: In the dynamic method.

MR. COOK: The normal recording process would be used just as if a sound record were to be made, except that the galvanometer would be excited by means of an oscillator.

MR. CARLSON: Have you any information as to the uniformity in either the recording or reproducing beam?

MR. COOK: That is rather difficult to remember. I think that in practice, the deviation in the better optical systems is of the order of 15 per cent from a uniform illumination as the beam is traversed from one side to the other.

MR. CARLSON: How much of the total loss, then, would you attribute to lack of uniformity within the scanning beam itself, and due to, as you stated, scattered light from the system?

MR. COOK: I should attribute most of the losses, as discussed in the paper, to scanning losses. Non-uniform illumination would produce a non-linearity which would cause an amplitude loss in proportion to the amount permitted. In this case, amplitude losses from this cause were not as serious as the other losses discussed. A very definite indication of that was seen in the data for the prints as presented in Fig. 17. In this case, the losses were found to be very much greater than was the case for the negatives obtained by the use of the square-wave mask in a field of uniform illumination. It is significant that non-uniform illumination did not exist during the printing operation, while scattered light was known to be present.

While in practice, every known improvement should be made, the amount of this form of variation of illumination present in the better forms of optical systems may be regarded, at least for present purposes, as a second order effect, which would become relatively more important as the primary losses are further reduced. I believe that test data may be found in the literature substantiating this viewpoint.

MR. KELLOGG: I would be interested to have Mr. Cook express his idea as to whether, of the two methods that have been in considerable use for testing of film losses, namely, the modulated steady tone and the square wave, he feels that one is a closer approximation to actual recording conditions than the other. I can conceive of one being defendable as against the other on the score of being a closer approximation to the waves you actually had to record.

MR. COOK: If I understand Mr. Kellogg correctly, one of the methods mentioned is dynamic and the other is static. I believe my position would be something like this: the choice will depend upon what one wishes to find out. For example, if one wishes to determine experimentally what the scanning losses, as defined in the paper, might be under a particular set of conditions, I am of the

opinion that the static, square-wave method would be much superior; in fact, I do not see how the other method may be employed in this particular problem and still yield results having sufficient exactness. If, however, an experimentally obtained number is desired to express the percentage of the scanning loss due to the aperture alone from a standpoint of light translation through a shaded geometrical trace, I think that in all probability one is forced to employ the dynamic method. However, he must be prepared to face the necessity of knowing something about the mechanics by which that loss occurs, and I confess I know no way of determining that with the desired precision. I do not know whether this exactly answers Mr. Kellogg's question or not.

MR. KELLOGG: Not entirely. I am thinking about the spectrum of the square wave that you are employing. For example, if you start with a 500-cycle wave, the amplitude of the successive harmonics (which will be at 500-cycle intervals) goes down inversely as the frequency. How nearly would that represent the distribution of amplitudes in sound as actually recorded? The square wave is not in exact imitation, and neither is the steady tone.

MR. COOK: Well, that is rather difficult, because not only the subject matter but the level of the sound to be recorded varies widely. In order for a variation in applied amplitude to effect these losses, it would be necessary for some considerable non-linearity to exist in the recording medium. I think it is well established that for the conditions used in practice, no evidence of sufficient non-linearity has been found. However, I believe that analyses have been published which show that the amplitudes of the higher frequencies in speech and music are in general materially reduced as the frequency is increased, and as a crude approximation, the reduction varies from inversely with the frequency to some higher rate of decrease. The square-wave method of analysis has harmonics whose amplitudes decrease inversely with the frequency. Of course, in applying a test wave to a galvanometer one may choose any amplitude desired but there are other circumstances which follow with the use of recording optical systems in experimental work. As has been mentioned, one of these is lens flare. With the presence of this difficulty, I do not know how to experimentally determine the aperture and optical system losses accurately enough to segregate those losses due solely to the film. Since cne determines the overall losses very accurately by the dynamic method, it has been made a necessary companion of the static, square-wave method in this work.

THE USE OF PHOTOELECTRIC EXPOSURE-METERS IN THE HOLLYWOOD STUDIOS*

W. STULL**

Summary.—*The use of photoelectric exposure-meters by Hollywood studio cameramen is definitely increasing. Such meters are universally employed on Technicolor productions, and are also employed by an increasing majority of studio cinematographers for monochrome exterior scenes. In general, cameramen consider conventional types of photoelectric meters unsuitable for use on interior scenes. For use under studio interior lighting a meter of especial precision in the low-brightness range is necessary and a direct-reading, rather than a reflection-reading, type would be preferred by many. In the opinion of many leading cameramen, a photometer reading directly in foot-candles, rather than an exposure-meter reading in photographic exposure units, would be preferable for this usage.*

The employment of photoelectric exposure-meters by the cameramen in the Hollywood studios is definitely increasing; however their use is by no means universal. In fact, the camera profession is divided into two argumentative camps, about equally divided, according as they favor or condemn these meters.

A great deal of enthusiasm is notable among the proponents of each view. The non-users of meters, especially, bristle with indignation at the mention of such mechanical aids. Their typical reaction is much like that of the late director Richard Boleslawsky when, in directing a Technicolor production, he found the camera crew religiously using a photoelectric meter.

"Why waste time on such foolishness," he asked, "a real cameraman doesn't need anything like that. Why, so-and-so, who photographed my last picture would only need to smell a strip of film to know all about it and how to shoot it!"

The irony of the situation is best appreciated when one knows that the man named happens to be one of the most enthusiastic users of photoelectric meters!

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* Received April 28, 1938.

** Hollywood, Calif.

Among the cinematographers photographing black-and-white productions, the use of photoelectric exposure-meters is almost wholly restricted to the making of exterior scenes, for several reasons. The majority of these cinematographers state that all factors of interior lighting are so familiar and so completely under control that there is little need for other aid. There is much to support this contention. Until the very recent introduction of the new super-speed films, the technic of studio interior cinematography differed considerably from that in many other photographic fields. Lenses are almost invariably used at their maximum apertures, ranging from $f/2.7$ to $f/2.3$. The lighting is therefore built up to a fairly standard level, so familiar that it can well be determined visually. Further, individual lighting technic varies enormously, according to the individual's methods of balancing illumination. So far as the writer is aware, no scientific survey of this situation has ever been made; but based upon his own observation over a period of many years, he would say that there is a difference of more than 200 per cent between the extremes of illumination that would be used by equally capable low-level and high-level "lighters" to obtain comparable results with identical film and processing. Another very important factor is that many cameramen, including many who use the device enthusiastically on exterior scenes, feel that no meter at present available has sufficient sensitivity in the low intensities to prove a satisfactory guide for their work on the stage.

But if such meters are not used extensively in filming interior scenes, they are used quite extensively whenever a company works outdoors or on location. Not less than half of the more noted cinematographers employ these devices under such conditions. Many follow their meters religiously.

The methods of using the meters vary with the individual. Recently when discussing the problem with three equally distinguished members of the profession, the writer found three quite different methods of using the meter. Perhaps the most popular technic is to position the meter according to the angular field of the lens used. Thus in making a long-shot, for which a 40-mm. or 50-mm. lens is most frequently employed, the reading is taken with the meter at the camera position. For closer shots—two-shots, waist and knee-length figures, *etc.*—the meter is read approximately halfway between the actor and the camera, which for such shots uses a 75-mm. lens. For close-ups, made often with a 4-inch lens, the reading is taken

with the meter about a third of the way from the actor to the camera.

Other outstanding cinematographers prefer the so-called "brightness-range" method, taking separate readings of extremes of shadow and highlight and averaging the results, or using the shadow readings as guides in building up the illumination, either with reflectors or booster lights, to a known minimum-exposure level.

Such readings are in almost all cases taken after the lighting has been balanced visually, after which any minor changes suggested by the meter readings are made. This appears to be the most economical of time.

Those who use the photoelectric meter are almost invariably highly enthusiastic over its value. One cinematographer recently told the writer of a scene in which he filmed a number outdoors, under trees, with six cameras photographing two singers, simultaneously from different angles. By the use of his meter he was able to adjust the lighting and exposure so accurately that all six negatives printed on the same printer light.

Another one told of how he had been unexpectedly assigned to a production, replacing a colleague. Here again his meter helped him overcome great extremes of lighting that had proved troublesome for his predecessor.

He mentioned also another production, in which he had photographed the dramatic action, while another man had filmed the background scenes. Both had used meters, and the two portions of the film matched so perfectly as to quality, exposure, and negative density that the studio heads expressed extreme amazement.

The Weston and General Electric are the only types of meters used. The latter has been available for so short a time, however, that while several of them are in use, it may be said that the Weston is the only type in widespread use in this field. Almost without exception, the older model *617* is the favorite, due to its greater sensitivity range and to a general feeling that it is the most dependable.

The considerably narrower angle scanned by the newer types of meter is considered a definite advantage, but not as yet enough to overcome the preference for the older type. The ideal instrument would in the opinion of virtually all cinematographers be one the scanning angle of which was identical with that of the lenses most commonly used, notably the 50-mm. lens which covers a horizontal

angle of 25 degrees, and the 40-mm. lens, now used almost as frequently, which covers an angle of 30 degrees.

A universally desired adjunct to the ideal meter would be a hood or sunshade which would screen from the cell not only the undesired rays from the sky, *etc.*, but also reflected light from large adjacent areas of light-colored walls, sea, sand, pavement, *etc.*, which ordinarily introduce a definite element of error into the meter readings. Several cinematographers habitually take their meter readings holding the meter in the matte box of their camera. Others, like the writer, hold the meter in such a way that the over-folded fingers of both hands form a sunshade for the cell. A few cinematographers have had special sunshades made for their meters. Some form of sunshade is probably more generally desired than any other single feature.

Almost equally desired is greater sensitivity in the low-intensity light ranges, so that the meter could be used for interior cinematography under artificial lighting. A meter that could be used interchangeably for both direct and reflection readings would also be welcomed.

There is, in addition, a very general opinion among the leading cameramen that the successful meter for professional use must be of the direct-reading, rather than the reflection type. For this purpose (interior scenes) many cinematographers would definitely prefer a meter reading directly in foot-candles, rather than in terms of photographic exposures. In their work, they point out, camera exposure settings are virtually fixed: the actual problem is that of building light-intensities to known levels, dependent upon the effect desired, and securing a fairly constant balance between highlight, shadow, and half-tone areas. A multirange photometer, comparable perhaps to the Weston model *614* but coördinated to panchromatic sensitivity and with a cell mounted on an extension cable, would be more useful for this than the conventional exposure meter.

The photocell meters now in use have proved remarkably durable. Many cinematographers make it a point to have their meters tested either at the completion of each production or immediately prior to the start of each new film. Very few have found reason for more than occasional routine repairs and adjustments. This record may be partly due to the fact that when in use these meters are not as a rule carried in accessory kits, and thus subject to rough handling, but almost invariably are carried upon the person of either the chief cinematographer or his operative (second) cinematographer. In

some cases the writer has known both of these individuals to carry and use their own meters, carefully checking the readings of the two instruments against each other.

It may be mentioned in this connection that all the meters used in monochrome cinematography are the personal property of the cinematographers who use them. While camera equipment itself is now almost invariably the property of the studio, photoelectric meters, despite their growing popularity, have not as yet been incorporated as official parts of the camera outfits. It is definitely a tribute to the practical worth of these meters that so many cinematographers have spent their own money to obtain them.

The most notable use of photoelectric meters in Hollywood is of course their application in Technicolor cinematography. In this they have for some years been universally used. The practice goes back to the introduction of the three-color Technicolor process in 1934, although some experimental use of the device was made prior to that, in the latter days of Technicolor's former two-color process. For the past four years, however, photocell photometers have been a standard part of every Technicolor camera outfit, and their use a standard part of regulation procedure.

The meter used on Technicolor sets is the standard Weston "studio model" *603* meter. In this application the meter cells are usually fitted with special filters compensating their color-sensitivity to a close approximation of the visual color-sensitivity curve. The meters are invariably used for direct reading, never for reflection readings. The standard procedure is to take three meter readings from approximately the position of the principal actor in the scene. The meter is held level, and one reading is taken with the cells facing directly toward the camera and two other readings facing 45 degrees to the right and 45 degrees to the left.

Until quite recently, such readings were taken for every camera set-up, and whenever any important change was made in lighting between takes of the same scene. These readings were carefully recorded and the information filed for future reference. This procedure served a double purpose: In the first place, it gave the cinematographer valuable help in keeping his illumination reasonably within the range of film sensitivity and processing limitations. Second, and of even greater importance, the existence of such records materially helped the mastery of a process that was new and relatively unexplored.

In some quarters it has been believed that this use of photometers in Technicolor photography was done to insure that the cinematographer adhered to rigidly set-up lighting formulas. Such was not the case. The rumor probably originated by a misinterpretation of the natural fact that the Technicolor laboratory required reasonable adherence to a normal standard of illumination if normal negatives and print-quality were to be had. No attempt was at any time made to use this procedure to dictate the balancing of lighting. This was always left to the discretion of the cinematographer in charge. The matter of effect-lighting was also left to the individual's judgment.

The technic of the Technicolor process has by now become fairly well established. Sufficient Technicolor productions have been made to give the Technicolor staff cinematographers a practical knowledge of the lighting limitations of the process, comparable to the general knowledge of similar limitations in monochrome cinematography. Therefore the use of the photronic meters is by no means so extensive as it necessarily was while the knowledge of the process was being amassed. The meters are still used, and their readings still recorded; but the meters are now used more as a guide to the cinematographer, as a supplement to his judgment, than as a measure of performance. The records of the readings are also proving of considerable value in instances where scenes must for any reason be retaken or amplified after considerable lapses of time. Thus while meter readings are not now so generally taken on every camera set-up, readings are still taken of key scenes on any set or sequence, thus affording a guide in matching the scenes in the event of retakes or added scenes. Such readings are generally taken, as well, for future guidance, in scenes calling for effect-lightings, and the like.

The value of these records can hardly be overestimated. Several Technicolor cinematographers have commented to the writer on the assistance they have received from these records in instances where, perhaps, one man had commenced a production, or possibly made preliminary, pre-production photographic tests of unusual conditions, and had been replaced during actual production by another cameraman. The records made possible a much better continuity of photographic treatment and quality than could otherwise have been possible.

The maintenance of these meters has of course been given careful attention. All the meters used by Technicolor camera crews are subjected to weekly inspection and to tests against standard meters

and illuminometers. Any irregularities are immediately remedied. In general these instruments appear to have made a very good record of durability in service usage.

Technicolor's use of photoelectric meters is having a marked influence on the use of such devices by monochrome cinematographers. An increasing number of cinematographers directly in the employ of the major studios, and heretofore active in making only black-and-white productions, are being assigned either to photographing Technicolor productions in the studios of their employers, or to studying Technicolor with a view to such future assignments. These men are almost universally gaining a new respect for the value of photronic meters. When they return to their routine work of filming black-and-white productions, many of them obtain their own meters and adapt the technic to monochrome cinematography. In at least one instance, a cinematographer after completing his first Technicolor production had the Technicolor engineers adapt a standard meter to his requirements.

It may therefore be said that the use of photoelectric exposure meters is becoming more general in the Hollywood studios, and is universal in natural-color cinematography. It is almost certain that within a relatively short time the use of these instruments will have become universal for black-and-white exterior scenes. The trend of opinion is that only the introduction of a completely satisfactory professional meter is needed to make the use of these instruments equally universal in interior cinematography.

THE STABILITY OF THE VISCOSE TYPE OF OZAPHANE PHOTOGRAPHIC FILM*

A. M. SOOKNE AND C. G. WEBER**

Summary.—*Viscose Ozaphane, a new type of film with a base of regenerated cellulose sheeting, and having certain advantages for record use, was tested to determine its comparative stability. Its stability was compared with that of cellulose nitrate, and also with that of cellulose acetate, which is widely used for slide-films and which has been found to be a very stable material for preserving records in libraries. The viscose type of film apparently is not suitable for permanent records, but does appear to have properties to recommend its use for reading-room copies that can be replaced when they become unserviceable. The stability was determined by measuring changes in the chemical and physical properties under accelerated aging. The changes observed were increase in acidity and copper number, and decrease in viscosity, weight, and flexibility.*

CONTENTS

(I) INTRODUCTION

Viscose Ozaphane, a relatively new type of motion picture film, was investigated with reference to its suitability for use as a record material. In this new type of film, a light-sensitive dye incorporated within the base performs the function of the emulsion coating on the conventional type of film now in use. The film tested had a base of transparent, viscose sheeting about 0.002 inch in thickness, plasticized with glycerin to obtain greater flexibility. The new type

* Presented at the Fall, 1938, Meeting at Detroit, Mich.; received October 3, 1938.

** National Bureau of Standards, Washington, D. C.

of film is of particular interest for record purposes for several reasons. It is grainless, gives high contrast, is slow-burning, the image is not readily damaged by scratching, and the film is only one-third as thick as the films of the emulsion type. The cellulose acetate film now used for record purposes has been found in previous studies[1] to be a very stable material when properly made[2] and properly processed photographically. The purpose of this study was to determine the relative stability of this type of Ozaphane film.

(II) DETERMINATION OF STABILITY BY ACCELERATED AGING

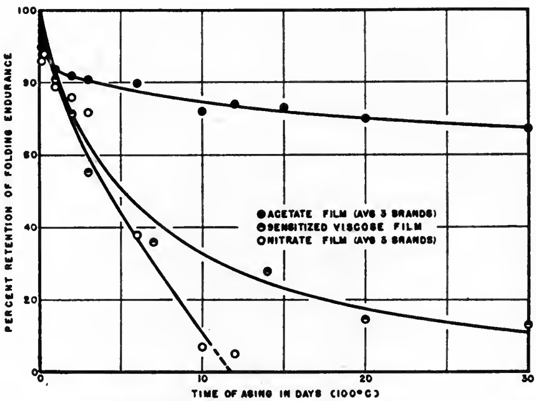
The stability of the new type of film was determined by measuring changes in its chemical and physical properties under accelerated aging. The accelerated aging treatment used was the same as that previously employed in evaluating acetate and nitrate films, namely, that of heating in dry air at 100°C. This test had formerly been found suitable for paper.[3,4] Loss of flexibility of papers and films, measured by a folding endurance test, is the most significant property because the flexibility is most sensitive to changes produced by deterioration. Measurements of the loss of weight on heating were also made. Other tests consisted in determining the decrease in viscosity of solutions of the film, and increase in the copper number and in acidity measured as *p*H. To assist in interpretation of the results, data previously[5] obtained for acetate and nitrate films under comparable aging treatments are included in the graphs for purposes of comparison.

(III) EFFECTS OF ACCELERATED AGING

(*1*) *Loss of Folding Endurance.*—The Schopper folding endurance tester, which is an instrument widely used for determining the folding endurance of paper, was used to measure the effects of aging on the flexibility of the film. Results of tests with the M. I. T. folder indicated that it was unsatisfactory because of excessive stretching of the specimens under test; and the film was found to be too thin to be tested successfully in the Pfund tester, which had been used for acetate and nitrate films. All folding tests on the Ozaphane film were made under constant atmospheric conditions of 50 per cent relative humidity and 75°F, the conditioning time being 24 hours for all specimens. The standard humidity of 65 per cent was not selected because stretching of the specimens under test was troublesome at that humidity. Control and aged specimens were conditioned and

tested under identical conditions, and all specimens were humidified by adsorption to avoid variations attributable to hysteresis in moisture sorption.

The effects of oven-aging on the folding endurance of Ozaphane as compared to acetate- and nitrate-base films are shown graphically in



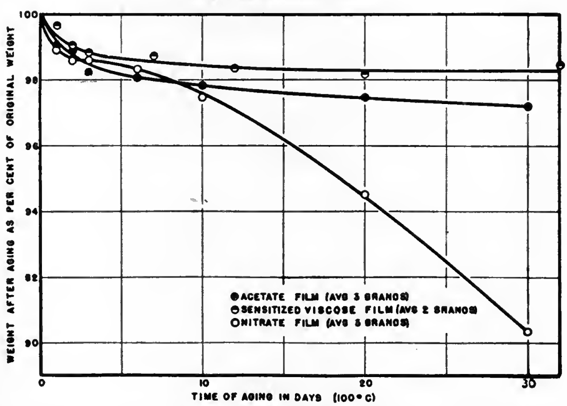
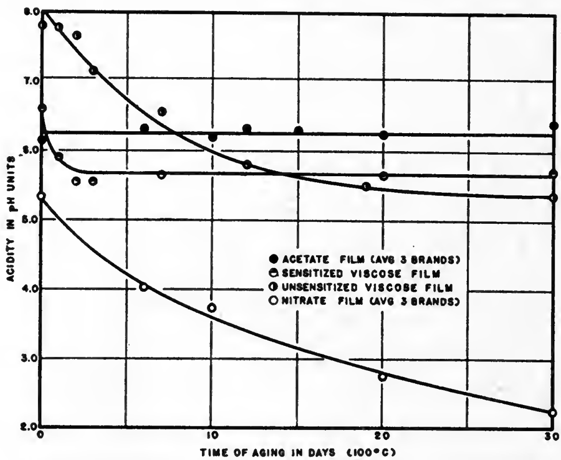


FIG. 1. (*Upper*) Effect of oven-aging upon flexibility of viscose Ozaphane film as compared to effects of similar treatment of acetate and nitrate film.

FIG. 2. (*Lower*) Loss of weight during oven-aging of viscose Ozaphane, acetate, and nitrate films.

Fig. 1. The results show a more rapid loss of flexibility under the heat test for Ozaphane than for the acetate-base film. It was, however, much more resistant than the nitrate-base film. After 30 days of oven-aging, the acetate retained approximately 67 per

cent of the original strength while Ozaphane retained only 13 per cent. None of the nitrate film retained any measurable folding endurance after 15 days of heating.



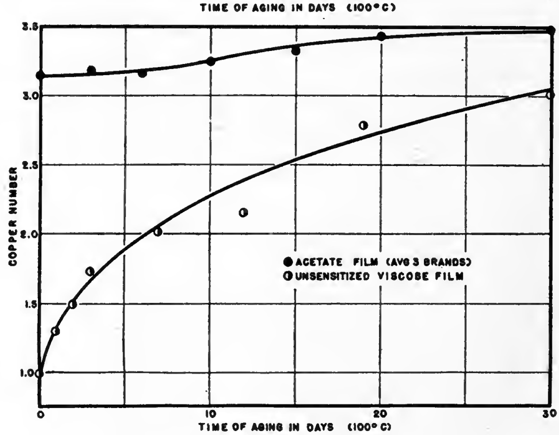


FIG. 3. (*Upper*) Effect of oven-aging upon acidity of record films.
FIG. 4. (*Lower*) Change of copper number during oven-aging; viscose Ozaphane and acetate films.

(2) *Loss of Weight.*—Oven-aging caused losses of weight for all types of films. However, the Ozaphane type showed only slight losses even for extended periods of heating. Fig. 2 shows loss in weight for Ozaphane, acetate, and nitrate films. The relatively

rapid initial decrease for acetate and nitrate films was probably caused by loss of residual solvents and plasticizers. On further heating the nitrate continued to lose appreciably through the escape of gaseous products of decomposition. The slight loss for Ozaphane was apparently plasticizer with possibly a little dye. All weighings were made after conditioning at 65 per cent relative humidity and 70°F.

(3) *Increase in Acidity.*—Chemical degradation of cellulosic materials is often accompanied by increased acidity. The changes in acidity of Ozaphane with aging were followed by means of *p*H determinations. The method used consisted in heating 1 gram of the ground material in 100 milliliters of distilled water of *p*H 6.0 to 7.0 for 1 hour in a steam bath, then measuring the *p*H of the extract with a glass electrode. The results obtained on both sensitized and unsensitized Ozaphane are shown in Fig. 3, which includes also data on aqueous acetone solutions of acetate- and nitrate-base film for purposes of comparison. The unsensitized Ozaphane showed a gradual increase in acidity with aging; however, the *p*H value was 5.4, which is moderate, after 30 days. The unsensitized film was intermediate in this respect between the acetate, which showed no measurable increase in acidity, and the nitrate, the acidity of which increased markedly on aging. Sensitized Ozaphane showed little change of *p*H after one day of heating, possibly because of buffering action of the dye in the film, some of which went into solution during extraction.

(4) *Increase in Copper Number.*—The copper number of cellulose is defined as the number of grams of copper reduced from the cupric to the cuprous state by 100 grams of the material under defined conditions. An increase of copper number is accepted as indicative of degradation of a cellulosic material; hence, the rate of increase during accelerated aging is considered a measure of stability. Fig. 4 shows the effects of accelerated aging on the copper number of unsensitized Ozaphane film and acetate-base film. The tests were made in accordance with the official method of the Technical Association of the Pulp and Paper Industry.[6] Unsensitized Ozaphane was used for the copper number determinations to avoid errors introduced by the reducing effect of the dye in the sensitized film. Although the copper number for unaged acetate-base film is relatively high, it changes very slowly on aging, the increase being 10 per cent for 30 days of aging. The increase for Ozaphane was 200 per cent for the

same treatment, which indicates definitely poorer stability under oven-aging.

(5) *Decrease in Viscosity.*—Data on the viscosity of solutions of cellulosic films provide the most reliable measure of their chemical degradation. According to Staudinger[7] the specific viscosity of long-chain molecules is directly proportional to the molecular weight, for dilute solutions of equal concentration. Molecular breakdown should therefore be accompanied by a proportional decrease in specific viscosity. Clibbens and Ridge[8] have shown that decreases in strength of cotton fibers produced by a variety of reagents are accompanied by corresponding decreases in the viscosities of their solutions.

The effects of accelerated aging on the viscosity of Ozaphane were determined by measuring the viscosities of solutions before and after various aging periods. The procedure used was that recommended by the British Fabrics Research Committee[9] and described by Clibbens and Little,[10] except that the concentration of ammonia in the standard cuprammonium solvent was 240 grams per liter as recommended by Clibbens and Geake.[11] The measurements were made at 21 ± 0.05°C, using solutions containing 2 grams of dry Ozaphane per 100 milliliters of solution. Hill and Weber[12] determined the viscosities of acetate and nitrate films by using acetone solutions containing 1 gram of film per 100 milliliters of solution. Acetone could not be used for Ozaphane because it is not a solvent for cellophane.

Fig. 5 is a graphic comparison of the retention of viscosities of acetate, Ozaphane, and nitrate films. The acetate retained more than 90 per cent of its original specific viscosity after 30 days of aging, while the Ozaphane films retained less than 60 per cent, and the nitrate 6 per cent. Here again the Ozaphane is intermediate in chemical stability between the stable acetate-base and unstable nitrate-base film.

(IV) SUMMARY AND CONCLUSIONS

The data indicate that the Ozaphane type of film having a viscose base is definitely inferior to good acetate film as regards stability under accelerated aging. It is not suitable for permanent records but apparently it has sufficient stability for positives for reading-room use. Its stability is comparable to that of ordinary sulfite wood-fiber papers which are known to last 25 years or longer under or-

dinary conditions if they are well made. Since the reading-room copies that are in use will doubtless become largely unserviceable from mechanical wear in less than 25 years, greater stability for that purpose does not appear essential. The Ozaphane type of film has certain advantages for use as positives: it is grainless, gives high contrast, is only one-third as thick as acetate, and has no emulsion to become scratched during projection and handling.

Although the viscose-base film apparently is not sufficiently stable for permanent records, it is not designed for use where the highest permanence is required. Negative films are in reality the master records, and the dyes employed at present in Ozaphane are too slow to permit its use for original photographs.

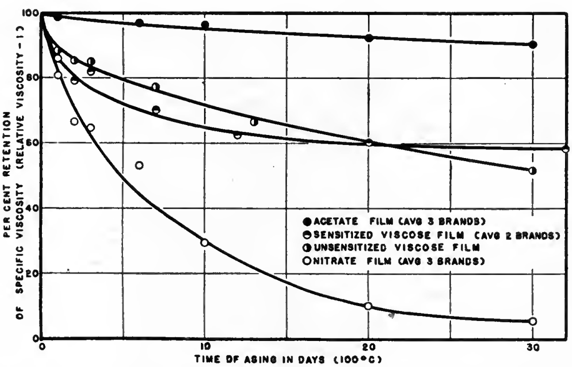


FIG. 5. Effect of oven-aging upon viscosity of viscose Ozaphane, acetate, and nitrate films.

It is quite possible that the stability of the Ozaphane type of film can be improved by using for a base a sheeting having higher initial purity. It is understood that a film of this kind has recently been developed and investigation of it is planned as a further part of this work.

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Note.—Since completion of the study reported above the National Bureau of Standards has made a similar study of Ozaphane film composed of cellulose acetate. When this film was heated for 72 hours at 100°C, the base was found to be as stable as that of the emulsion type of film; it compared favorably with the best grades of permanent-record papers. As far as the stability of the base is concerned, the suitability of the acetate Ozaphane film for permanent records can be determined as suggested for the emulsion type in the Bureau Miscellaneous Publication M158, "Evaluation of Motion-Picture Film for Permanent Records," except that it is not necessary to test for sodium hypochlorite or for cellulose nitrate, and a M. I. T. folding endurance tester should be used instead of the Schopper. Film having a M. I. T. folding endurance of not less than 150 double folds at a tension of 500 grams, and relative humidity of 50 per cent, should be satisfactory. There was practically no fading of the image under the heat test. On exposure to carbon-arc light for 48 hours the image faded somewhat but retained good legibility.

REPORT OF THE STANDARDS COMMITTEE*

Summary.—*Semiannual report of the Committee. The present report deals with (1) cores for 35-mm. and 16-mm. motion picture film; (2) sound-track dimensions; (3) 16-mm. sound-film sprocket; (4) definition of safety film; (5) reduction ratio for 35-mm. to 16-mm.; (6) universal perforation; and (7) "variable-area" vs. variable-width.*

The principal items under consideration by the Standards Committee at the present time are as follows:

(*1*) *Cores for 35-Mm. and 16-Mm. Motion Picture Film.*—Drawings for cores with dimensions and tolerances for 35-mm. and 16-mm. film have been given initial and final approval by the Standards Committee and are being published in an early issue of the JOURNAL. There are two questions in regard to these drawings on which there has been some debate:

In the first place, the tolerances adopted have been fairly large; for example, the recommended hole size for the 35-mm. core is 1.012 to 1.028 inches, whereas the maximum diameter for the shaft is 1.000 inch. This gives a possible clearance of 0.028 inch between the shaft and the inside of the core. It was the consensus, however, that this clearance made no practical difference and that a range of values was necessary in order to permit different manufacturers to use the various plastics and other materials that they find satisfactory.

The second question involved is the question of standardizing two types of cores, *viz.*, the so-called positive core and the so-called negative core. The positive core has a keyway and is intended to fit on a round shaft with a key or stud to keep the core from revolving on the shaft. The second type of core, or the so-called negative core, is intended to fit on a shaft having a keyway. This type of core, therefore, has a key molded into the core and, consequently, will not go over the round shaft. In adopting as standard only the so-called positive core, the Standards Committee realizes that for some time to come the negative cores will be used, and that possibly the change

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* Presented at the Fall, 1938, Meeting at Detroit, Mich.; received Nov. 11, 1938.

to the positive type of core may never occur. However, the film manufacturers and some of the apparatus producers believe it would be of benefit to the trade if a single type of core could be used, and for that reason the single standard has been adopted.

(*2*) *Sound-Track Dimensions.*—A thorough study of the best dimensions for the 35-mm. sound-track is being made by a committee of the Academy of Motion Picture Arts & Sciences. Our Committee is, therefore, waiting until the Academy committee has announced its findings before taking any action on this matter.

(*3*) *16-Mm. Sound-Film Sprocket.*—A preliminary drawing has been given initial approval and has been sent out to the various members of the Standards Committee and to various manufacturers for criticism. The principles involved in handling singly perforated film are somewhat different from those used in handling doubly perforated film. For example, with 16-mm. sound-film, it is common practice to have the sprocket-teeth entirely fill the holes, at least in the lateral dimension, and guiding of the film in the picture gate by means of the sprocket-holes is almost universal. If such guiding is used, the sprocket-teeth must be rounded with a radius of curvature greater than that used for the film, or inevitably damage will result. It is the opinion of some that it is too early to standardize on sprockets for 16-mm. sound-film and that correct sprocket design depends entirely upon the design of the projector on which it is to be used.

(*4*) *Definition of Safety Film.*—The Standards Committee has given initial approval to the definition and specification of safety film recommended for adoption at a meeting of the International Standards Association at Berlin on June 28, 1938. Inasmuch as there are rather important differences of opinion with regard to the advisability of approving this definition, it is included herewith in full in order that we may have a fuller discussion:

Definition.

Safety film means a film that is slow-burning and difficult to ignite.

A film is called slow-burning if its burning time for a piece of film of 30 cm. takes more than 45 seconds. For films having a thickness of less than 0.08 mm., the burning time must be more than 30 seconds. The burning time is determined according to paragraph *a*.

A film is termed difficult to ignite if it does not ignite at 300°C within 10 minutes.

Safety film must contain not more than 0.36 per cent of nitrate nitrogen.

Testing Method.

(*a*) *Testing of Burning Time.*

(*1*) The film is freed from emulsion in warm water and is dried in open air at 18° to 22°C and 40 to 50 per cent relative humidity for 12 hours.

(*2*) The sample to be tested shall be 35 cm. long, and a mark provided 5 cm. from the top.

(*3*) The sample to be tested shall be hung horizontally edgewise between two stretched wires, if it have two rows of perforations. The wires shall be threaded through the holes at intervals not greater than 32 mm. and in such a way that the used holes are displaced against each other. The wire shall not be thicker than 0.5 mm.

(*4*) The burning time is calculated from the moment when the flame reaches the mark until the sample is fully burned. This time shall be determined in three tests, immediately after drying, in a room free from air currents. No test shall give a burning time less than the fixed minimum.

Marking.

Safety film that comes up to these conditions may be marked *Safety Film* but only in connection with the name or the trade-mark of the manufacturer.

The determination of inflammability is reserved for a later meeting of ISA Committee *36*.

The above definition and testing procedure constitute essentially the old Lehman burning test, with an additional specification as to the maximum amount of cellulose nitrate. This agrees with the minimum amount in the listings of the Underwriters' Laboratory, but is about half as great as the maximum amount in their listing.

(*5*) *Reduction Ratio for 35-Mm. to 16-Mm.*—This question is in the hands of a sub-committee under the Chairmanship of J. A. Maurer. The committee has not yet reported its findings.

(*6*) *Universal Perforation.*—The question of a universal perforation with the basic dimensions of the Bell & Howell and with the general shape of the positive perforation is still under study. A report by P. Arnold, Chairman of the sub-committee on this subject, is expected soon.

(*7*) "*Variable-Area*" *vs.* "*Variable-Width.*"—The question of standardizing the term *variable-area* or *variable-width* as the definitive name of one kind of sound-track has been referred to the Standards Committee by the editors of the JOURNAL. Letters were mailed to all the members of the Standards Committee asking the following questions:

(*1*) Whether or not the Society should standardize on one or the other of these terms.

(*2*) Whether in their opinion one term was more desirable than the other.

(*3*) Whether in their neighborhood one term was in wider use than the other erm.

The replies were approximately 2 to 1 in favor of the term *variable-area* principally because that is the term in common use, although quite a number of the members indicated their belief that the term *variable-width* was somewhat more technically correct. A little over a majority of the members who replied were in favor of establishing a standard.

The letters indicated great diversity of points of view, depending mainly upon the connections of the members—whether the matter was looked at from the point of view of the film or of the recording method. It was pointed out that in the November, 1931, issue of the JOURNAL, both terms were listed in the "Glossary of Technical Terms Used in the Motion Picture Industry," and that, although the term *variable-width* may have been preferred editorial practice of the Society, nevertheless the two terms were synonymous.

The motion was made, seconded, and unanimously approved, that in the next report of the Standards Committee it be stated that the Standards Committee had canvassed the situation and had found that the term *variable-area* is more generally used than the term *variable-width*, but, however, that the two terms should be regarded as synonymous, as indicated by the Glossary of November, 1931.

E. K. CARVER, *Chairman*

P. H. ARNOLD	C. L. FARRAND	T. NAGASE
F. C. BADGLEY	G. FRIEDL, JR.	N. F. OAKLEY
M. C. BATSEL	H. N. GRIFFIN	G. F. RACKETT
L. N. BUSCH	A. C. HARDY	W. B. RAYTON
A. COTTET	L. B. HOFFMAN	C. N. REIFSTECK
L. W. DAVEE	R. C. HUBBARD	H. RUBIN
A. C. DOWNES	E. HUSE	O. SANDVIK
J. A. DUBRAY	C. L. LOOTENS	J. L. SPENCE
P. H. EVANS	K. F. MORGAN	J. VAN BREUKELEN
R. E. FARNHAM		I. D. WRATTEN

REPORT OF MEMBERSHIP AND SUBSCRIPTION COMMITTEE*

In the report of the Committee presented last spring the prediction was made that if business conditions improved the Society's membership would number 1400 by the end of this year. Actually the influx of new members during the past six months has been such that we should have far surpassed this figure had it not been for the large number of delinquent members.

On April 15th the membership was 1333, the largest in the history of the Society. Since then we have added 121 members, which should have brought the figure up to 1454, another new high. Unfortunately, however, since April 15th, 125 members have become delinquent and a few have resigned, with the result that the net membership as of September 30th was 1309.

While the reinstatement of delinquent members is not the function of the Membership Committee, the matter of delinquencies is of chief concern to us because our upward climb is thus impeded. Our sincere hope is that before the end of this year a very substantial number of those now delinquent will have come back into the fold.

As of September 30, 1938, totals were as follows: 6 Honorary Members, 138 Fellows, 361 Active Members, and 804 Associates, making a net total of 1309. Seven applications, 6 Active and 1 Fellow, are pending.

Our loss in subscriptions during the same period has been on about the same scale as our membership delinquencies. On April 15th we had a total of 422 subscriptions. Since then 32 have been added. However, 87 were lost during the same period.

Perhaps the pronounced recession period through which we have just passed has been responsible in whole or in part for the membership delinquencies and subscription losses just referred to, and now that brighter skies are ahead, we shall regain the ground lost.

E. R. GEIB, *Chairman*

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* Presented at the Fall, 1938, Meeting at Detroit, Mich.; received October 31, 1938.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

19 (Sept., 1938), No. 9

Dr. Carter Answers Vital Queries Regarding Metal Film Development (pp. 356–359).	R. W. Carter
Erpi Introduces Sound Recorder for Professional 16-Mm. Film Men (p. 364).	
Abrams Builds Plane and Camera for Aerial Photographic Mapping (p. 370).	

Electronics

11 (Sept., 1938), No. 9

A Sound Illusion Pre-Amplifier (pp. 14–15).	C. F. Sheaffer
Combination Tones in Non-Linear Systems (pp. 20–21).	F. Massa
A Laboratory Television Receiver—III (pp. 22–25).	D. G. Fink
Magnetic Recording (pp. 30–32).	S. J. Begun

International Photographer

10 (Sept., 1938), No. 8

New Eastman Films (p. 1)	
M-R Introduces Duarc (pp. 1–2).	
New Canady Recorder (p. 6).	
Theatre Sound Optical Systems (pp. 25–27).	C. N. Batsel

International Projectionist

13 (Sept., 1938), No. 9

Common Causes of Breakdown in Theatre Sound Systems (pp. 7–8, 10, 30).	A. Nadell
Emergency Measures Applicable to Motor Control Failure (pp. 11–14).	L. Borgeson
Notes on Time-Lag in Gas-Filled Photo-Electric Cells (pp. 14–15).	A. M. Skellett
Notes on SMPE 16-Mm. Test-Films (p. 15).	
The Theory of Commutation. *II* (pp. 16–19).	Engineering Dept., National Carbon Co.

Craft Opinion on Reverse Prints Sharply Divided; Exchanges Hit (pp. 28–29).

Push-Pull Recording and Reproduction: The What, Why and How (pp. 20–22). — F. T. JAMEY

Kinematograph Weekly

259 (Sept. 22, 1938), No. 1640

Light Intensity and Colour Films (p. 39). — R. H. CRICKS

Kinotechnik

20 (Sept., 1938), No. 9

Ozaphantonfilm (Ozaphane Sound-Film) (pp. 232–237). — A. NARATH

Der Stereoskopische Film (Stereoscopic Film) (pp. 237–238). — W. THORNER

Die Bedeutung des stereoskopischen Bildwurfes beim Film (Importance of Stereoscopic Projection for Film) (pp. 238–240). — W. PISTOR

Motion Picture Herald

132 (Sept. 24, 1938), No. 13

Cosmocolor, New Two-Color Process Is Demonstrated (p. 24).

La Technique Cinematographique

9 (Aug., 1938), No. 92

L'enregistrement Sonore sur Bandes Reduites et sur Papier (Recording Sound on Reduced Strips and on Paper) (pp. 1241–1242). — R. HARDY

Normes des Emissions de Television (Television Standards) (p. 1242).

PROGRAM

FALL, 1938, CONVENTION, DETROIT, MICH., HOTEL STATLER

(*As actually followed in the Sessions*)

MONDAY, OCTOBER 31, 1938

9:00 a.m. Registration.

10:00 a.m. **Business and General Session.**

Opening remarks by President S. K. Wolf.

Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*

Report of the Membership Committee; E. R. Geib, *Chairman.*

Election of Officers.

"Underwater Cinematography;" E. R. F. Johnson, Mechanical Improvements Corp., Moorestown, N. J. (*Demonstration.*)

"The Spectroheliokinematograph;" R. R. McMath, McMath-Hulbert Observatory, University of Michigan, Ann Arbor, Mich. (*Demonstration.*)

"The Future of Commercial Motion Pictures;" F. J. Herman, Jam Handy Picture Service, Inc., Detroit, Mich.

"Oskar Messter—German Pioneer;" H. Traub, Berlin, Germany.

12:30 p.m. **Informal Luncheon.**

Addresses by:

Hon. Richard W. Reading, Mayor of Detroit, Mich.

Mr. Jamison Handy, President of Jam Handy Corporation, Detroit, Mich.

Mr. George W. Trendle, President, United Detroit Theaters Corporation, Detroit, Mich.

2:00 p.m. **Sound Session.**

"Some Practical Accessories for Motion Picture Sound Recording;" R. O. Strock, Eastern Service Studios, Long Island City, N. Y.

"Improving the Fidelity of Disk Records for Direct Playback;" H. J. Hasbrouck, Jr., RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)

Report of the Standards Committee.

Society Business.

"Characteristics of Film-Reproducing Systems;" F. Durst and E. J. Shortt, International Projector Corp., New York, N. Y.

"Some Production Aspects of Binaural Recording for Sound Motion Pictures;" W. H. Offenhauser, Jr., New York, N. Y., and J. J. Israel, Brooklyn, N. Y. (*Demonstration.*)

"Unidirectional Microphone Technic;" J. P. Livadary, Columbia Pictures Corp., Ltd., Hollywood, Calif., and M. Rettinger, RCA Manufacturing Co., Inc., Los Angeles, Calif.

8:00 p.m. Motion Picture Program.

Showing of recent feature motion pictures and short subjects.

TUESDAY, NOVEMBER 1, 1938

9:30 a.m. General Session.

"A Machine for Artificial Reverberation;" S. K. Wolf, Acoustic Consultants, Inc., New York, N. Y.

"A Motion Picture Dubbing and Scoring Stage;" C. L. Lootens, Republic Productions, Inc., North Hollywood, Calif., M. Rettinger, RCA Manufacturing Co., Inc., Hollywood, Calif., and D. J. Bloomberg, Republic Productions, Inc., North Hollywood, Calif.

"Some of the Problems Ahead in Television;" I. J. Kaar, General Electric Co., Bridgeport, Conn.

"Some Television Problems from the Motion Picture Standpoint;" G. L. Beers, E. W. Engstrom, and I. G. Maloff, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)

2:00 p.m. Laboratory Session.

"Some General Characteristics of Chromium-Nickel-Iron Alloys as Corrosion-Resisting Materials;" F. L. LaQue, International Nickel Co., Inc., New York, N. Y.

"A Color-Temperature Meter;" E. M. Lowry, Kodak Research Laboratories, Rochester, N. Y.

"Technicolor Adventures in Cinemaland;" H. T. Kalmus, Technicolor Motion Picture Corp., Hollywood, Calif.

"Chemical Analysis of an *MQ* Developer;" R. M. Evans and W. T. Hanson, Jr., Kodak Research Laboratories, Rochester, N. Y.

"Opacimeter Used in Chemical Analysis;" R. M. Evans and G. P. Silberstein, Kodak Research Laboratories, Rochester, N. Y.

"Latest Developments in Variable-Area Processing;" A. C. Blaney, RCA Manufacturing Co., Inc., Los Angeles, Calif., and G. M. Best, Warner Bros. Pictures, Inc., Burbank, Calif. (*Demonstration.*)

7:30 p.m. Semi-Annual Banquet.

Introduction of Officers-Elect.
Presentation of Journal Award.
Presentation of SMPE Progress Medal.
Entertainment and dancing.

WEDNESDAY, NOVEMBER 2, 1938

9:30 a.m. Studio-Lighting–Theater Session.

"The Evolution of Arc Broadside Lighting Equipment;" P. Mole, Mole-Richardson Co., Hollywood, Calif.

Report of the Studio Lighting Committee; C. W. Handley, *Chairman.*

"The Lighting of Theater Interiors;" F. M. Falge, General Electric Company, Cleveland, Ohio. (*Demonstration.*) Discussion led by L. A. Jones and B. Schlanger.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

"Coördinating Acoustics and Architecture in the Design of the Motion Picture Theater;" C. C. Potwin, Electrical Research Products, Inc., New York, N. Y., and B. Schlanger, New York, N. Y.

"The Copper Sulfide Rectifier as a Source of Power for the Projection Arc;" C. A. Kotterman, P. H. Mallory & Co., Indianapolis, Ind.

2:00 p.m. 16-Mm. and General Session.

"A 16-Mm. Studio Recorder;" R. W. Benfer, Electrical Research Products, Inc., New York, N. Y. (*Demonstration.*)

"A Super Sound and Picture Printer;" O. B. Depue, Burton Holmes Films, Inc., Chicago, Ill.

"A New 16-Mm. Developing Machine;" J. M. Blaney, Cinandagraph Corp., Stanford, Conn.

"New Sound Recording Equipment;" D. R. Canady and V. A. Welman, Canady Sound Appliance Co., Cleveland, Ohio.

"The Evaluation of Motion Picture Films by Semimicro Testing;" J. E. Gibson and C. G. Weber, National Bureau of Standards, Washington, D. C.

"The Stability of the Viscose Type of Ozaphane Photographic Film;" A. M. Sookne and C. G. Weber, National Bureau of Standards, Washington, D. C.

"A Silent Wind Machine for the Production Stage;" F. G. Albin, United Artists Studio Corp., Hollywood, Calif.

"Independent Drive for Camera in the A-c. Interlock Motor System;" F. G. Albin, United Artists Studio Corp., Hollywood, Calif.

"A Semi-Automatic Follow-Focus Device;" J. Arnold, M-G-M Studio, Culver City, Calif.

"A New Single-System Recording Attachment for Standard 35-Mm. Cameras;" A. Reeves, Art Reeves Motion Picture Equipment Co., Hollywood, Calif.

SOCIETY ANNOUNCEMENTS

OFFICERS FOR 1939

Election of officers and governors of the Society for 1939 was completed at the Detroit Convention on October 31st. The results of the election are given on page 557 of this issue of the JOURNAL.

ATLANTIC COAST SECTION

On November 18th, in the North Ballroom of the Hotel New Yorker, New York, N. Y., two papers on the subject of television, originally presented at the Detroit Convention, were re-presented, namely,

"The Road Ahead for Television," by I. J. Kaar, General Electric Company, Bridgeport, Conn.

"Some Television Problems from the Motion Picture Standpoint," by G. L. Beers, E. W. Engstrom, and I. G. Mallof, RCA Manufacturing Company, Camden, N. J.

The two papers aroused considerable interest and elicited much discussion. Plans for future meetings of the Section include papers by F. C. Gilbert on motion picture theater equipment servicing (December); E. Epstean on the contributions of Daguerre, on the occasion of the centenary of Daguerre's announcements of his work to the French Academy of Science (January); E. I. Sponable on newsreel recording (February); and W. B. Rayton on projection lenses (March).

MID-WEST SECTION

At a meeting held at the Bell & Howell Laboratory, Chicago, Ill., on October 25th, W. D. Myers of the National Theater Supply Company presented a paper on "A New Theater Sound System."

Following the paper, the film "High Lights and Shadows," an industrial motion picture film of the Eastman Kodak Company, was presented.

SPRING 1939 CONVENTION

The Spring, 1939, Convention will be held at Hollywood, Calif., with headquarters at the Hotel Roosevelt, April 17th to 21st, inclusive. Members are urged to bear the dates in mind so that they may make their plans in advance for attending the Convention. It is suggested that vacations may be combined with the trip to the Coast.

NEW AMENDMENTS

At the Detroit Convention on October 31st, a number of proposed amendments of the Constitution and By-Laws were acted upon by the Society in session. The

ensuing paragraphs give the substance of the amendments and are followed by the amendments in their exact original and new wordings, for comparison.

CONSTITUTION

Article IV, Officers

It is proposed that the term of office of the Executive Vice-President be extended to two years, in view of the fact that the terms of all the other vice-presidents are two years.

Original wording:

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President and Past-President shall be two years; of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two years; and of the Executive Vice-President, Secretary, and Treasurer, one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

Proposed wording:

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President, the Past-President, the Executive Vice-President, the Engineering Vice-President, the Editorial Vice-President, the Financial Vice-President, and the Convention Vice-President shall be two years, and the Secretary and the Treasurer one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

(*This amendment is to be voted upon by the voting membership of the Society by letter ballot. Ballots, and a complete transcript of the discussion on this proposal at the Convention, will be mailed to the voting membership in the near future.*)

The following By-Laws were approved at the Convention in accordance with the existing procedure for amending the By-Laws, and are therefore now in effect:

BY-LAW I

Membership

Fellow membership may no longer be applied for.

Original wording:

Sec. 2.—All applications for membership or transfer shall be made on blank forms provided for the purpose, shall give a complete record of the applicant's education and experience.

New wording:

Sec. 2.—All applications for membership or transfer, except for Honorary or Fellow membership, shall be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow membership may not be applied for.

Fellow membership will be granted by the Board of Governors. A Committee on Fellow membership will be established to recommend periodically to the Board of Governors the names of those eligible for elevation to the grade of Fellow.

Original wording:

Sec. 3 (b).—Applicants for the grade of Fellow shall give as reference at least three Fellows in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

New wording:

Sec. 3 (b).—Fellow membership may be granted upon recommendation of at least three-fourths of the Board of Governors.

BY-LAW II

Officers

Hitherto, holding office in the Society has been restricted to Honorary and Fellow members. The new amendment extends the privilege to Active members.

Original wording:

Sec. 1.—An officer or governor shall be an Honorary member, a Fellow, or an Active member. After January 1, 1935, Active members shall not be eligible to hold national office in the Society.

New wording:

Sec. 1.—An officer or governor shall be an Honorary, a Fellow, or Active member.

BY-LAW VII

Dues and Indebtedness

Dues beginning January 1, 1939, will be $15 for Fellows and Active members, and $7.50 for Associate members. At present the dues are $20 for Fellows, $10 for Active members, and $6 for Associate members.

Original wording:

Sec. 1.—The annual dues shall be twenty dollars ($20) for Fellows, ten dollars ($10) for Active members, and six dollars ($6) for Associate members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the publication. No admission fee will be required in any grade of membership.

New wording:

Sec. 1.—The annual dues shall be fifteen dollars ($15) for Fellows and Active members and seven dollars and fifty cents ($7.50) for Associate members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the publication. No admission fee will be required for any grade of membership.

This By-Law describes the procedure to be followed in case of delinquent members. The original wording permitted retaining delinquent members on the mailing list of the JOURNAL *for six months; the new wording reduces this to four months.*

Original wording:

Sec. 4.—Members shall be considered delinquent whose dues remain unpaid for four months. Members who are in arrears of dues for 30 days after notice of such delinquence, mailed to their last address of record, shall have their names posted at the Society's headquarters, which shall be the General Office, and notices of such action mailed to them. Two months after becoming delinquent, members shall be dropped from the rolls if non-payment is continued.

New wording:

Sec. 4.—Members shall be considered delinquent whose annual dues for the year remain unpaid on February 1st. The first notice of delinquency shall be mailed February 1st. The second notice of delinquency shall be mailed, if necessary, on March 1st, and shall include a statement that the member's name will be moved from the mailing list for the JOURNAL and other publications of the Society before the mailing of the April issue of the JOURNAL. Members who are in arrears of dues on June 1st, after two notices of such delinquency have been mailed to their last address of record, shall be notified their names have been removed from the mailing list and shall be warned that unless remittance is received on or before August 1st, their names shall be submitted to the Board of Governors for action at the next meeting. Back issues of the JOURNAL shall be sent, if available, to members whose dues have been paid prior to August 1st.

Delinquent members may be dropped from the rolls by action of the Board of Governors. Members dropped from the rolls for non-payment of dues may resume membership in the Society only by applying as new members.

Original wording:

Sec. 5.—Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

New wording:

Sec. 5(a).—Members whose dues remain unpaid on October 1st may be dropped from the rolls of the Society by majority vote and action of the Board, or the Board may take such action as it sees fit.

(*b*) Anyone who has been dropped from the rolls of the Society for non-payment of dues shall, in the event of his application for reinstatement, be considered as a new member.

(*c*) Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

BY-LAW XI

Amendments

A new procedure is established for amending the By-Laws in case no quorum is obtainable at a Convention of the Society, in which case proposed amendments may be validated by vote of the Board of Governors.

Original wording:

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by a two-thirds vote by ballot of the members present at the meeting, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation of the Board of Governors signed by any ten members of Active or higher grade.

New wording:

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by the affirmative vote of two-thirds of the membership present at a meeting who are eligible to vote thereon, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation to the Board of Governors signed by any ten members of active or higher grade, provided that the proposed amendment or amendments shall have been published in the Journal of the Society, in the issue next preceding the date of the stated business meeting of the Society, at which the amendment or amendments are to be acted upon.

Sec. 2.—In the event that no quorum of the voting membership is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the By-Laws upon receiving the affirmative vote of three-quarters of the Board of Governors.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ALLA, R.
38 Avenue des Champs Elysees,
Paris, France.

BATTLE, G. H.
Canadian National Carbon Co., Ltd.,
805 Davenport Rd.,
Toronto, Canada.

BENHAM, H. J.
616 Keith Building,
Cleveland, O.

BLUHME, A. B.
646 N. Lotus Ave.,
Chicago, Ill.

BOSTELMANN, T. A.
3315 Olive St.,
St. Louis, Mo.

COAR, R. J.
1421 Massachusetts Ave., N. W.,
Washington, D. C.

COOK, J. A.
4956 Thekla Ave.,
St. Louis, Mo.

DOWNS, G. W., JR.
6900 McKinley Ave.,
Los Angeles, Calif.

EAGLES, J. P.
16–22 Australia St.,
Camperdown, N. S. W.,
Australia.

GLEASON, J. P.
Movietone News, Inc.,
1118 So. Michigan Ave.,
Chicago, Ill.

GUNSBURG-SHICK, H.
National Theater Supply Co.,
1560 Broadway,
New York, N. Y.

HOTINE, W.
℅ Films, Inc.,
330 West 42d St.,
New York, N. Y.

ISRAEL, J. J.
1598 East 28th St.,
Brooklyn, N. Y.

JONES, R. W.
100 Broadview Ave.,
New Rochelle, N. Y.

LIPPERT, O.
7002 Sheridan Rd.,
Chicago, Ill.

MARTIN, S. M.
Miller Broadcasting System,
113 West 57th St.,
New York, N. Y.

MORRIS, R. M.
22 Mountainview Rd.,
Millburn, N. J.

MULLER, R.
Rome, via Guitinio Sella 20.
Italy.

MURUA, A. P.
Campichuelo 553,
Argentina.

NAPOLETANO, T.
3910 French Rd.,
Detroit, Mich.

PACE, G. C.
3134 Elliott Ave.,
Dayton, O.

PAI, B. K.
Lamington Rd.,
Bombay 4, India.

ROSENBERG, T.
1560 Broadway,
New York, N. Y.

STOWELL, T. C.
Department of Health,
State of New York,
Albany, N. Y.

TICKES, S.
4927 N. Lawndale,
Chicago, Ill.

WALTER, E.
Rua Sao Pedro 268,
Coixa Postal 849,
Rio de Janeiro, Brazil

WHEELWRIGHT, G. W. 3RD.
Polaroid Corporation,
285 Columbus Ave.,
Boston, Mass.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

BOUTELLEAU, C.
296, Rue Lecourse,
Paris XV^e, France

EDMONDS, A. L.
4248 Deenan Blvd.,
Los Angeles, Calif.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

	No.	Price
1920	10	$1.00
1921	12	1.00
1922	15	1.00
1924	19	1.25
	20	1.25

	No.	Price
1925	21	$1.25
	22	1.25
	23	1.25
	24	1.25
1926	25	1.25
	26	1.25
	27	1.25
	28	1.25

	No.	Price
1927	29	$1.25
	32	1.25
1928	33	2.50
	34	2.50
	35	2.50
	36	2.50
1929	37	3.00
	38	3.00

Beginning with the January, 1930, issue, the Journal of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and Journals should be placed through the General Office of the Society and should be accompanied by check or money-order.

SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

Aims and Accomplishments.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

Journal Index.—An index of the Journal from January, 1930, to December, 1935, containing author and classified indexes. One dollar each.

SMPE Standards.—The revised edition of the *SMPE Standards and Recommended Practice* was published in the March, 1938, issue of the Journal, copies of which may be obtained for one dollar each.

Membership Certificates.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

Journal Binders.—Black fabrikoid binders, lettered in gold, holding a year's issue of the Journal. Two dollars each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

Test-Films.—See advertisement in this issue of the Journal.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED INDEXES

VOLUME XXXI

JULY–DECEMBER, 1938

AUTHOR INDEX, VOLUME XXXI

JULY TO DECEMBER, 1938

CLASSIFIED INDEX, VOLUME XXXI

JULY TO DECEMBER, 1938